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Methodology to Inventory, Classify, and Prioritize Uncontrolled Waste Disposal Sites

Monroe County Environmental Management Council
Rochester, NY

Prepared for

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16. Abstract

A comprehensive method to inventory uncontrolled waste disposal sites integrates all available historic, engineering, geologic, land use, water supply, and public agency or private company records in order to develop a complete and accurate site profile. Detailed information on site contents may not be available but areas of potential impact can be evaluated. Where people or drinking water supplies are affected, further investigation is indicated.

Historic aerial photographs provide the accuracy and documentation required to compile a precise record of site boundaries, points of access, and adjacent land use. Engineering borings for construction projects in the vicinity of suspected sites are integrated with geologic information to construct reasonable hydrogeologic models to evaluate potential leachate impact on water wells or nearby inhabitants.

Sites are systematically ranked using matrices with appropriate variables, such as geology, land use, or distance to water wells. This kind of an evaluation is a necessary step in the prioritization of sites where little is known about contents and where numbers of sites preclude a comprehensive drilling and testing program.

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A METHODOLOGY TO INVENTORY, CLASSIFY, AND PRIORITIZE UNCONTROLLED WASTE DISPOSAL SITES

by

Ann B. Nelson
Louise A. Hartshorn
Monroe County Environmental Management Council
Rochester, New York 14614

and

Dr. Richard A. Young
State University of New York
Geneseo, New York 14451

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Project Officer

Roy B. Evans
Advanced Monitoring Systems Division
Environmental Monitoring Systems Laboratory
Las Vegas, Nevada 89114

ENVIRONMENTAL MONITORING SYSTEMS LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
LAS VEGAS, NEVADA 89114

NOTICE

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ABSTRACT

A comprehensive approach has been developed for use by local governments to inventory active and inactive waste disposal sites for which little or no information is available, and to establish priorities for further investigation. This approach integrates all available historic, engineering, geologic, land use, water supply, and public agency or private company records to develop as complete a site profile as possible. Historic aerial photographs provide the accuracy and documentation required to compile a precise record of site boundaries, points of access, and adjacent land use. Engineering borings for construction projects in the vicinity of suspected sites can be integrated with geologic information to construct reasonable hydrogeologic models to evaluate potential leachate impact on water wells or nearby inhabitants. Sites are systematically ranked in terms of potential hazard based on current land use, hydrogeology, and proximity to water wells. Greatest attention is given to those sites which could impact public or private drinking water supplies. This kind of evaluation is a necessary step in the prioritization of abandoned dump sites where little is known about contents and where numbers of sites preclude a comprehensive drilling or testing program. Case histories from Monroe County, New York, indicate that a well-designed study provides a conservative estimate of the number of large dump sites which deserve further consideration. The Monroe County study also provided a comprehensive, 50-year inventory of all potentially significant sites in a large urban area (Rochester, N.Y.) in which at least 90 percent of initially identified targets were either eliminated or were not classified as high priority sites.

This report was submitted in fulfillment of Contract No. 14043 under the sponsorship of the U.S. Environmental Protection Agency. This report covers a period from July 1981 to July 1982, and work was completed as of November 1, 1982.

PREFACE

The adverse effects of chemical leachate migration from former waste disposal sites became a major public concern in the late 1970's. In response, Congress passed the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) on December 11, 1980. Better known as "Superfund," this law provides a fund for the cleanup of inactive hazardous waste sites. Section 105 directs that procedures and standards for locating hazardous waste sites and determining priorities for cleanup be developed based on relative risk to the public health, welfare, or the environment. The criteria must take into account the population at risk, hazard potential of the substances, potential for contamination of drinking water supplies, potential for direct human contact, and potential for destruction of sensitive ecosystems. States are required to annually nominate priority sites for remedial action based on the above factors.

In 1978, Monroe County, N.Y., at the direction of the County Legislature, began a process to discover and evaluate known and unknown waste disposal sites. The problem proved complex, but a wide range of valuable information sources were identified and utilized.

In 1980, EPA reviewed the county's effort and awarded a contract for the completion of the methodology. The preparation of this manual, which outlines Monroe County's procedures for identifying and characterizing waste disposal sites and for establishing priorities for further investigation, is the final product of this grant. EPA funded the effort to assist the agency with its responsibility to discover and screen sites under the National Contingency Plan. The methods can be used to locate unknown sites and to develop more detailed information on the many reported sites about which little is known.

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LIST OF ABBREVIATIONS

CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980; also known as "Superfund"
CPM	Critical Path Management
DEC	New York State Department of Environmental Conservation
EMC	Monroe County Environmental Management Council
EPA	United States Environmental Protection Agency
EROS	Earth Resources Observation System
LRC	Monroe County Landfill Review Committee
NASA	National Aeronautics and Space Administration
NCIC	National Cartographic Information Center
NCP	National Contingency Plan
NOAA	National Oceanic and Atmospheric Administration
NYS	New York State
NYSDOT	New York State Department of Transportation
PERT	Program Evaluation Review Technique
RCRA	Resource Conservation and Recovery Act of 1976
SAR	Site Activity Record
SCS	Soil Conservation Service
SHWRD	EPA Solid and Hazardous Waste Research Division
SIA	Surface Impoundment Assessment Model
SIC	Standard Industrial Code
USDA	United States Department of Agriculture
USGS	United States Geological Survey

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A number of individuals from New York county and state agencies participated in various stages of this study. Members of the Monroe County Landfill Review Committee (LRC) played key roles in the development of the methodology. Dr. Joel Nitzkin, County Health Director and Chairman of the LRC, effectively coordinated the study among the various state and county agencies. At various points, Richard Burton, director of the Monroe County Health Department Laboratory, and Dr. Harrison Sine, Jr., Vice-Chairman of the Monroe County Environmental Management Council, offered direction and insight as the methodology was refined. During the early stages, Frank Clark, Senior Sanitary Engineer for the Region 8 office of the New York State Department of Environmental Conservation (DEC), provided engineering expertise, access to important information sources, and support for the study in state offices in Albany. Donald Barry, Executive Director of the Industrial Management Council, provided valuable input from the industrial community.

Monroe County appreciates the support of former DEC Commissioner Robert Flacke; Norman Nosenchuck, DEC Director of Solid Waste; and Eric Seiffer, Director of Region 8, DEC. A grant from the DEC in 1979-80 enabled the county to pursue the study at a crucial stage in the project's development.

The completion of the work was made possible through the support of the U.S. Environmental Protection Agency (EPA). Mr. Harold Snyder, Office of Emergency and Remedial Response, Washington, D.C. recognized the value of the work and provided funding to complete the effort. Dr. Roy B. Evans, Project Director for the Environmental Monitoring Systems Laboratory of the EPA in Las Vegas, Nevada, provided the federal perspective needed for the generalization of the methodology.

John Earls, Frances Reese, and Patricia Terziani gathered data for the project. Interns Robert Patterson and Aaron Christiano assisted during the site clarification stage. James DeMocker carefully edited the final draft and made many excellent suggestions. Mr. DeMocker also constructed the PERT Demonstration Model and wrote the accompanying text. Completion of the final report would not have been possible without the support of Joanne Brand and Jan Wilson, who typed and corrected the various drafts.

Ann B. Nelson, Project Director
Louise A. Hartshorn, Research Assistant
Richard A. Young, Consulting Geologist

CHAPTER 1

INTRODUCTION

In the late 1970's the public became concerned about uncontrolled waste disposal sites that could pose a hazard to human health. In order to determine the location and impact of these sites, accurate information is needed on site locations, boundaries, contents, subsurface hydrogeologic conditions, and proximal land uses. Documentation of past waste disposal activities is, at best, incomplete and, in many instances, nonexistent. An accurate and inexpensive method is needed to develop site information based on existing data so that expensive drilling and testing programs can be focused on those sites of greatest potential hazard to human health.

This report describes a comprehensive approach that can be used by local governments, particularly counties and large municipalities, to inventory active and inactive sites for which little or no information is available, and to establish priorities for further investigation. The methods were designed by agencies in Monroe County, New York, in response to a 1978 county legislature request to locate hazardous sites and a 1979 New York State law requiring counties to identify suspected inactive hazardous waste sites and to report their locations to the New York State Department of Environmental Conservation (DEC). The study has at various times been financially supported by the County of Monroe, the State of New York, and the United States Environmental Protection Agency. This broad base of support illustrates the concern felt at all levels of government that uncontrolled hazardous waste sites be identified and their impacts accurately assessed so that potential health hazards can be identified and corrected. It also reflects the fact that limited available resources must be committed to cleaning up the worst sites.

The study was conducted under the direction of the Monroe County Landfill Review Committee (LRC). This committee, chaired by the county Director of Health, includes representatives from the county departments of Health, Planning, and the Environmental Management Council (EMC); the New York State Departments of Health and Environmental Conservation; the City of Rochester; and the local Industrial Management Council. The participation of individuals from this broad range of interests facilitated access to information and provided valuable direction and guidance to the project. The work program was funded through the Monroe County Environmental Management Council. Council staff organized and conducted the study, hired the consultants, and prepared reports for the committee's review.

The Monroe County approach provides a method for inventorying both known and unknown sites at the countywide level, accurately delineating site locations and boundaries, developing site profiles, and using geologic information to rank sites in terms of their potential impact on drinking water supplies and nearby populations. This is accomplished by integrating data from a variety of sources. Historic aerial photographs provide the accuracy and documentation required to compile a precise record of site boundaries, points of access, and adjacent land use. Interviews and files in various government agencies substantiate types of activity noted on the photos and provide information on water supply locations. Data from engineering borings for construction projects in the vicinity of suspected sites are integrated with geologic information to construct preliminary hydrogeologic models to evaluate potential leachate impact on water supplies or nearby inhabitants.

It should be noted that not all waste disposal sites will be evident on the historic aerial photographs. Some sites will be too small to detect (usually less than one-half acre). Others will be liquid waste disposed in areas other than surface impoundments. In some areas activity may have occurred between the years of available photography. Supplementary information on intervening years may be necessary to compile a more complete record of activity.

Sites are ranked using matrices with variables for geology and land use. Greatest attention is given to those sites which could impact either public or private drinking water supplies. The ranking scheme is based on the assumption that any site could contain hazardous waste because of past unregulated waste disposal practices. Rank is assigned according to potential impact on human health or drinking water rather than toxicity or quantity of waste because the chemical composition of the waste is generally unknown at this stage of the investigation.

When all the information has been collected and reviewed, the sites are ranked in each of the separate categories of 1) current land use, 2) hydrogeology, 3) proximity to water supplies, and 4) type of site. For example, the hydrogeology ranking process divides sites into higher, intermediate, and lower potential hazard based on eight geologic variables (permeability, separation from groundwater, etc.).

When all sites have been ranked in each of the four categories, a simple matrix can be used to develop an overall site ranking according to any combination of the four variables. For example: all sites positively identified as dumps can be placed in a matrix where the variables considered are *land use* and *geology*. Some of the resulting combinations in the matrix categories might be 1) dumps with *highest geologic hazard* and *continuous site occupancy*, or 2) dumps with *highest geologic hazard* and *part-time occupancy*.

Depending on the variables that might be considered most important in each region, the relative ranking derived from the matrix or matrices can be used to select priority sites for further testing or referral action.

Five basic steps are followed for inventorying and ranking sites. These steps correspond to the next five chapters of this report.

Site Identification:	Interpretation of historic aerial photographs, a search of agency records, and a public call-in campaign.
Site Characterization:	Refinement/confirmation of information through interviews with local officials, residents, and industrial representatives; review of agency files, street directories, tax records, and historic documents. Location of water supplies in close proximity to sites.
General Geologic Analysis:	Development of general hydrogeologic information on depth to groundwater and bedrock, hydraulic gradient, the character and permeability of the overburden and rock formations, and thickness of the overburden.
Hydrogeologic Hazard Analysis:	Evaluation of sites for potential impact of leachate on nearby water supplies and human populations based on geologic conditions.
Application of Methodology to Rank Sites:	Ranking of sites according to land use, geology, and proximity to water wells.

Chapter 6 also includes an example of the application of the methodology.

The tasks covered in each section are carried out by individuals with varying backgrounds and skills. Appendix A describes the organization of the study and the types of expertise required. A Program Evaluation Review Technique (PERT) model of the method is also presented in Appendix A.

The methods outlined in this report are a suggested approach based on the experience of one county. Other municipalities undertaking a similar study can adapt the approach to meet local needs and conditions. While the procedures described are for conducting a general inventory, the basic approach can also be used to investigate individual sites.

CHAPTER 2

SITE IDENTIFICATION

INTRODUCTION

This chapter describes a systematic method of inventorying active and inactive waste disposal sites. The approach provides information on undocumented sites as well as those briefly referenced in agency files but about which little is known.

The methodology uses historic black and white aerial photographs in stereographic pairs as the data base to search for unknown sites and to delineate accurate site boundaries. The photos also supply information on periods of operation and impacts on natural features and nearby residents. While these photographs serve as the primary source of information on site locations and activity, the data must be supplemented by researching old records, conducting interviews, and by a public call-in campaign. These secondary sources, when used without photo analysis, are often insufficient for locating sites and for determining boundaries, periods of operation, and potential impacts. The integration of all available resources is the key to accurate site identification and provides the most complete profile of site activity.

Procedures to identify and characterize active and inactive sites should meet the following objectives:

1. provide a method for locating sites for which there are no detailed records, and for verifying the location of known sites;

2. provide a means of accurately delineating site boundaries and determining periods of operation for active and inactive sites;

3. provide a method for compiling an historic profile of relevant activity on and adjacent to sites; and

4. develop a consistent and reliable technique for site identification and characterization that provides accurate, standardized information which can be used to compare sites and establish priorities for remedial action.

Site identification has two main components:

1. identification of known sites through a search of existing records and a public call-in campaign; and
2. identification of unknown sites and verification of the boundaries of known sites through interpretation of historic aerial photographs.

IDENTIFICATION OF KNOWN DUMP/LANDFILL SITES

The information on known sites is gathered by the research assistant (see Appendix A). Information on documented sites can be obtained from a number of sources:

- State and local government files
- United States Department of Agriculture (USDA) county soil maps/geologic quadrangle maps
- Historic sources
- Government publications on hazardous waste sites

A call-in campaign can provide additional information on sites; information from this source will have to be corroborated during the aerial photointerpretation stage.

State and Local Government Files

State and local health departments, state conservation or environmental protection departments, public works departments and other agencies that collect data relating to environmental quality, such as planning agencies and environmental councils, often have information on disposal sites. Health and conservation departments may have records covering specific sites for the last 10 to 20 years, including information on owners, operators, permits, and enforcement actions.

In Monroe County useful information was found in County Health Department files and the Solid Waste Division of the regional office of the New York State Department of Environmental Conservation. A 1964 Disposal Site Survey was found in the Monroe County Department of Planning library (1).

USDA County Soil Maps/USGS Geologic Quadrangle Maps

Recent and older versions of USDA county soil maps as well as U.S. Geological Survey (USGS) geologic quadrangle maps (surficial and bedrock) provide valuable information on dumps, pits and quarries, and artificially made land. This information can serve as a guide to the photointerpreter when the photos are being reviewed. Soil maps can be obtained from the USDA and the local Soil Conservation Service (SCS). Geologic quadrangle maps are available from the USGS (2).

Historic Sources

The local history section of public libraries will often have articles, newspaper clippings, and old photographs that identify waste disposal areas that have been noteworthy in the past. In addition to identifying sites, these sources can provide information on associated activities, users, owners, and operators.

Government Publications on Hazardous Waste Sites

An increasing number of reports on hazardous waste disposal sites and generators are being published by federal and state agencies. The federal reports include congressional surveys of large chemical companies (3) and reports on sites or waste characteristics submitted to the U.S. Environmental Protection Agency (EPA) by industries to meet the federal requirements of the Resource Conservation and Recovery Act of 1976 (RCRA) (4,5) and the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) (6), also known as "Superfund." In addition, many state governments have solid waste agencies that have conducted surveys of industrial and hazardous waste disposal practices within their borders (7,8). All states have conducted a survey of their worst uncontrolled sites as required by the National Contingency Plan (NCP) and CERCLA and submitted these to the EPA Office of Emergency and Remedial Response for the establishment of the National Priority List of the 115 worst sites, as of October, 1981.

Federal reports are available from the United States Government Printing Office and the National Technical Information Service in Washington (see Appendix B for addresses). State conservation agencies are generally the source of state or regional reports.

Call-In Campaign

In addition to researching documented sites, a public call-in campaign should be conducted to obtain information on sites that local citizens can remember but for which no records are available. The information from this source is not as reliable as the data obtained from official sources, but it can serve as a useful guide during air photointerpretation.

The call-in campaign is conducted by publishing a list of known sites in local newspapers and providing a phone number for reporting additional sites or providing more information on known sites. Telephone operators receiving the calls should have a standardized form to fill out for each site (Appendix C).

These forms become part of the permanent record of the study. In Monroe County the Health department released the list of sites and provided the switchboard to receive the calls.

Flyers requesting information on sites can also be prepared and distributed to town halls, housing projects, government agencies, community centers, and similar local groups (Appendix D).

The call-in campaign requires the cooperation of the news media and must be well publicized to be effective.

Recording Information

The information from all available sources is collected and reviewed. It is recommended that the general locations of all known waste disposal sites be marked with a dot on translucent mylar drafting film laid over topographic maps for the study area. The information on site locations will be general at this point. Photographic interpretation will verify the exact location and boundaries of these sites.

The sites are numbered by municipality using a two letter abbreviation for the municipality (i.e., Rochester Site No. 1 = RO 1). Site specific information is noted on a Site Activity Record (SAR) form (Appendix E). This form is used to record all pertinent information for each site and to provide an on-going record during later phases of the study.

IDENTIFICATION OF UNKNOWN SITES

This portion of the study should be performed by an individual with skills in air photo interpretation. The gathering of the basic aerial photographs and map resources is done by the research assistant (see Appendix A).

Survey of Photographic Resources and Collection of Materials

Before photointerpretation can be undertaken, a survey of aerial photographic resources must be completed to determine available flight years and the scale, completeness of coverage, and location of the photographs. It must be determined which sets of photographs are best suited to the study and whether these are readily available, can be borrowed, or must be purchased.

Aerial photographs are generally available at three-to-five year intervals from federal agencies such as the USDA, USGS, the National Aeronautics and Space Administration (NASA), the Earth Resources Observation System (EROS) Data Center, and the National Archives. A list of most federal agency coverage (excluding USDA photos) can be obtained free from the EROS Data Center in Sioux Falls, South Dakota. Local, state, or federal agencies may also compile lists of locally available photography, including photos from private mapping companies. Contacting private mapping companies directly may also produce photos not listed on the governmental inventories. Appendix B contains a complete listing of sources and addresses. It should be noted that a large gap in photographic coverage exists throughout the United States from 1940 to 1950 because of the war effort.

In Monroe County photos were available for 1930, 1938, 1951, 1958, 1961, 1963, 1966, 1967, 1968, 1970, and 1975-78 (composite). In the final study only photos for 1951, 1961, 1970, and 1975-78 were used routinely for the inventory of sites since the greatest volume of hazardous materials was assumed to have been generated during and after the Second World War. For the older urban industrialized area covering the City of Rochester, 1930 photographs were also included. For the largest and potentially most hazardous sites, intermediate years of photography were used to provide a more complete profile of site activity.

While the photographic resources are being identified and collected, base maps must also be obtained. USGS 1:24,000 topographic maps are recommended for recording both site locations and the geologic data described in Chapter 4. It is important that both data sets be recorded on maps of a common scale so that information on site locations and hydrogeologic effects can be readily compared. USGS topographic maps were chosen for several reasons. In addition to providing valuable information on quarries, gravel pits, settling ponds, and depressions, older editions can be compared to newer editions for changes caused by filling or construction activity. These maps contain all existing streets and highways and are updated periodically with uniform standards of accuracy. The latest editions of topographic maps are available from the federal government or local retail outlets. Older editions can be obtained on microfilm from the National Cartographic Information Center (Appendix B).

Before the final survey map can be prepared on the USGS topographic base map, the photointerpreter needs a larger scale map for accurately recording individual site boundaries. Orthophotomaps at the scale of 1"=200' are used when available to record detailed information on each site. These maps are enlarged paper prints of aerial photographs. When these are not available, planimetric maps at the same scale can be substituted.

Organization of the Photointerpretation Stage

The inventory of active and inactive sites is most easily conducted by dividing the survey area into sections corresponding to individual USGS 7-1/2 minute topographic quadrangle maps (1:24,000). The survey is conducted for one USGS quadrangle at a time.

The photointerpreter organizes the following materials for the study area:

1. the appropriate USGS 7-1/2 minute (15 minute if 7-1/2 minute not available) topographic map; and

2. aerial photographs for the selected years of study (in stereographic pairs).

The orthophotomaps will be obtained after the site locations are known since these are only needed for areas where activity has been noted.

Photographic Annotation

The photointerpreter begins by overlaying translucent mylar drafting film on the selected USGS quadrangle map. The locations of known sites are marked on the drafting film by a small dot to highlight areas where the photointerpreter should pay special attention (see p. 8). Experience has shown that the preliminary location and size of many sites may have to be revised based on information contained on the photos.

The photos for each quadrangle are systematically reviewed by year using stereo pairs, beginning with the earliest years and proceeding to the most recent. When relevant activity is observed, mylar drafting film is taped to one photo in the stereo pair. Since the film is translucent, the photos can still be viewed stereoscopically. The relevant activity is annotated on the drafting film and numbered sequentially by municipality. Types of sites that should be numbered include dumping, filling, lagoons, and junkyards. Features that should be noted but not numbered are extraction activities, adjacent industries that need to be identified, drainage patterns, wetland areas, access roads, trucks, smoke, and any other activities that could be significant. Special note should be made of barrels or containers. The boundaries of borrow, quarry, mining, or extraction areas should be delineated as a reminder to check newer photographs for subsequent filling or dumping. In general most sites are identified by observing either active dumping or filling activity, or by noting features such as uneven mounds or landscape changes that were not apparent on earlier photographs.

The photo identification number, flight year, one or two key road intersections, and a north arrow should also be noted on the drafting film to provide a permanent record of site activity by year. Figure 2-1 is an example of site annotation. Standard symbols shown in Appendix F should be used where possible.

Interpretive notes describing the types of activities observed on photos should be added directly to the drafting film taped to each photo. It is important to make notes directly on the drafting film covering each photograph at the time of interpretation to avoid forgetting pertinent site information as the study progresses.

Notes should be made on sites where supplemental information is necessary in order to determine the type of activity observed or concurrent occupants of adjacent buildings. Often the identification of nearby businesses provides valuable clues. Business or street directories for the years of photography can provide this information.

When interpreting information on aerial photographs, it is not always possible to distinguish between waste disposal and filling activity. Dumping/landfilling is the addition of wastes which may be hazardous, while filling is the addition of inert material in preparation for building or road construction. High volume disposal activity can be clearly noted, but there are many instances where filling can be observed with insufficient evidence to determine if waste was also disposed on the site. When annotating sites, the criteria in Table 2-1 should be used as a guide to distinguish waste disposal and filling activity.

The interpreter should have practical experience with landfill and dumping operations, extraction activities, and engineering construction practices in order to accurately apply the criteria. They should not be used by an individual unfamiliar with these techniques, since interpretation of the photographic clues requires judgement and skill.

The interpreter should be extremely careful to accurately characterize the type of activity noted on the photographs. Experience in the early stages of the Monroe County study indicated that, if care is not exercised, abandoned sand and gravel extraction areas, stockpiles, and disturbed land associated with construction activity can easily be misinterpreted as waste disposal. If the disposal of waste is not obvious or already known to have occurred in the area, it is better to indicate filling until more specific information can be obtained from other sources. The methods for obtaining this information are described in Chapter 3.

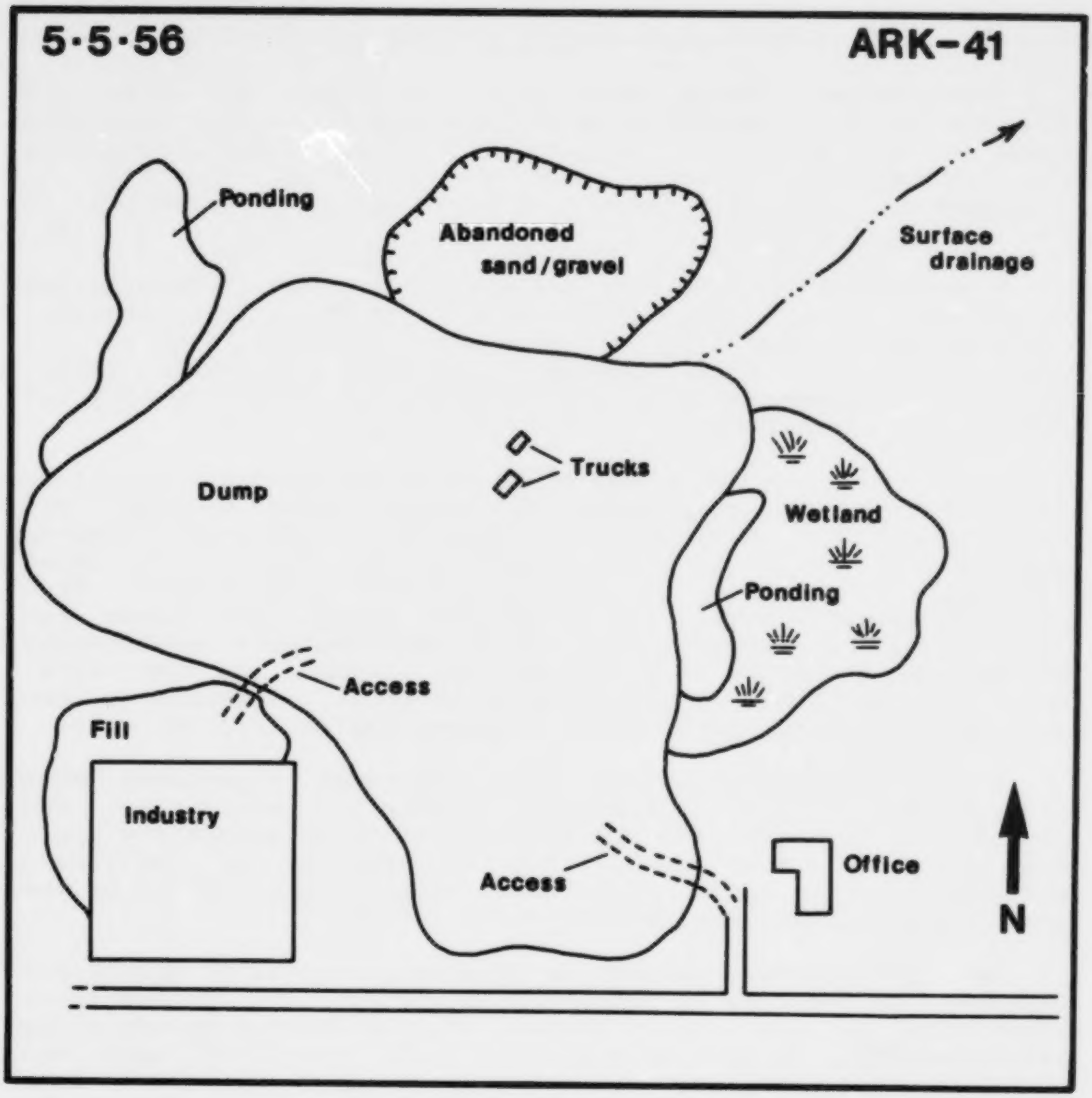

5·5·56
ARK-41
Ponding
Abandoned sand/gravel
Surface drainage
Trucks
Dump
Wetland
Ponding
Access
Fill
Industry
Access
Office
N

Figure 2-1. An example of site notation that would be recorded on a piece of drafting film attached to an aerial photograph.

TABLE 2-1. GENERAL CRITERIA FOR DISTINGUISHING WASTE DISPOSAL AND FILL AREAS

Waste Disposal Activity - Not all conditions are unique to waste disposal; some features may not be easily identified on small sites. Newer sites may show results of technological change (use of equipment) and recent state or federal regulations (stockpiles of cover material, sediment ponds, graded slopes, cell excavation construction method). Sites should be evaluated in conjunction with adjacent land use and industries. It should be remembered that sites may have been active between periods of available photography.

1. Material has a speckled black and white appearance or uneven coloration (recent clean fill is assumed to have a more uniform texture and light tone). Extensive dark grey to black tone often indicates fly ash or cinders from power plant, heating plant, or furnace slag.
2. There is obvious material mounded above surroundings or partially filling depression.
3. Steep embankment and scalloped edge of waste material evident, often in fan-shaped pattern extending into wetland, natural depression, or quarry/borrow pit.
4. Vehicle tracks are in evidence from machinery associated with the spreading of waste material (often in fan-shape pattern).
5. Photographic tone of the site is usually conspicuously different from (contrasts with) the surrounding area and land use. Usually lighter tone overall (except fly ash, cinders).
6. Well-traveled access roads are evident; trucks may be observed on photos in the process of dumping at the site.
7. Smoke from controlled or spontaneous fires, (especially evident on pre-1970 photos).
8. Barrel/container piles.
9. Small building on site for caretaker and/or equipment.
10. Evidence of junked autos or large appliances or tires (salvage materials usually in piles).
11. Stockpile of cover material for more recent sites.

12. Sediment containment ponds (for more recent landfills),trenches, or lagoons with obvious berms or dikes.

13. Signs of vegetation stress, leachate seeps, or discoloration of surface water, streams, or lakes.

Filling Activity - Assumed to be largely "clean" (uncontaminated) and inert. Fill activity usually implies short-term preparation of the site for building or road construction, whereas disposal activity is usually longer term. Series of photos or revised topographic maps may document areas where filling occurs rapidly, followed by the appearance of a highway, new building or structure, or parking areas.

1. Location has been identified on previous photographs as former excavation, low area, wetland, or depression. Surface area generally higher than on previous photos. (Not always distinguishable from dump sites if old.)

2. In early stage uniformly-sized and spaced mounded piles may be present. Area worked and leveled in later stage resembles plowed soil; light toned with smooth texture when fresh. Tracks from grading may remain visible for months or years if construction does not occur immediately.

3. For recent sites fill material stands out from background due to light tone (when less than a year old); later brush and or trees begin to appear but paths or sandlot ball activities may be evident.

Lagoons/Settling Ponds/Surface Impoundments

1. Bermed or excavated pits or trenches associated with evidence of other disposal activity, including dumping, barrels, or containers.

2. Depression generally water filled. Discolored inlet plume may be identified if active discharge pipe is present.

3. Settling pond associated with sewage treatment facilities are usually distinctive, round features with aeration booms.

4. Settling ponds/lagoons associated with industrial facilities.

Disturbed Land - Indicates investigation of other photographs or records is necessary.

1. Light tones without detectable topographic modification (implies low volume or little disturbance).
2. Different in tone and texture from surrounding area. Example: possibly staging area for construction activity.
3. Possible trails associated with recreational or other use (bikes, trails, horse paths).

Excavations - Source of possible waste disposal or filling activity requiring further evaluation with additional photographs.

Borrow Pits

1. Curved, sloping excavation walls; irregular, scalloped outline.
2. Usually lighter tone than surroundings.
3. Irregular, curving edges on depressions created by excavation and loading equipment; closely-spaced tracks in active working areas.
4. Spoil (boulders) or stockpiles in evidence.
5. Often can identify conveyor equipment or sorting and crushing machinery associated with a pond (for sediment trap and washing purposes).
6. Artificial drainage ditches to divert or drain surface water.
7. Intricate pattern of access roads connecting building and work areas.

Quarries or Strip Mines

1. Sharp jointed bedrock surfaces.
2. Horizontal terraces or "lifts" associated with rock removal.
3. Vertical walls with conspicuous right-angle edges.

4. Machinery (drill stands, conveyor belts, air compressor, rock crusher equipment, drag lines).
5. Artificial drainage ditches and pipelines to drain depressions.
6. Stockpiles of "prepared" rock (building stone) or spoil piles of rock and overburden. May be ringed with dike of overburden.
7. Generally, more permanent or elaborate buildings and equipment than borrow pits or landfills (may have railroad access spur).
8. Strip mines: Many follow contours in steep terrain. Often large acreage with spoil in regular patterns where not restored by regulation.
9. Underground mining: Spoil or tailing piles near entrance or processing plant.

Recording Information

After all the photos have been interpreted, the information is reviewed for all years and a complete, composite description of specific activities is recorded by year for each numbered site. This is most easily accomplished by noting all visible or suspected activity on the SAR form (Appendix E, Item 5).

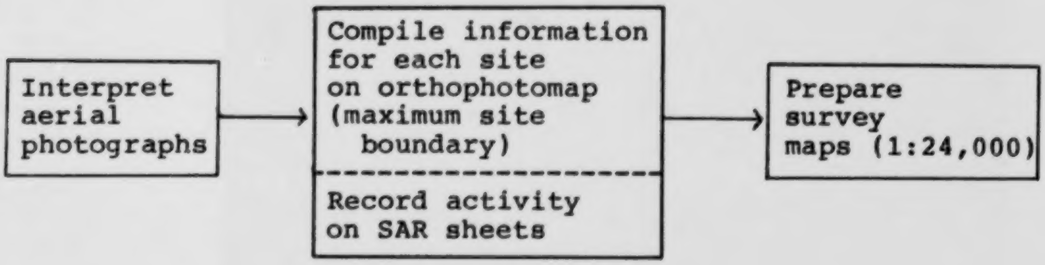
A maximum site boundary map is also prepared. This map is a compilation of information from each year of photography. The most accurate method of developing a site boundary is to transfer the information from each set of photographs to an orthophotomap or other large-scale map (1"=200'). These maps are obtained from local planning departments for each area where dumping, filling, junkyards, or lagoons have been noted. When orthophotomaps are available, accurate mapping can be done directly on these photographic sheets using landmarks common to all photographs (Figure 2-2). These maps not only assist in the construction of accurate site boundaries, but they are used in the more detailed site investigation work described in Chapter 3 and the geologic analysis described in Chapter 4.

Whether or not orthophotomaps are available, extreme care must be used in all instances when replotting any photographic information at different scales to insure that all boundaries are accurately recorded.

General Inventory Map

After the site boundaries are accurately drawn on the large scale orthophotomaps, they are transferred to the drafting film on the topographic map to complete the site inventory (Figure 2-3). The scale of the topographic maps permits direct comparison of information on site locations with geologic data described in Chapter 4.

The basic recording of information in the site identification phase is shown by the flow chart below.


Interpret aerial photographs
Compile information for each site on orthophotomap (maximum site boundary)
Record activity on SAR sheets
Prepare survey maps (1:24,000)

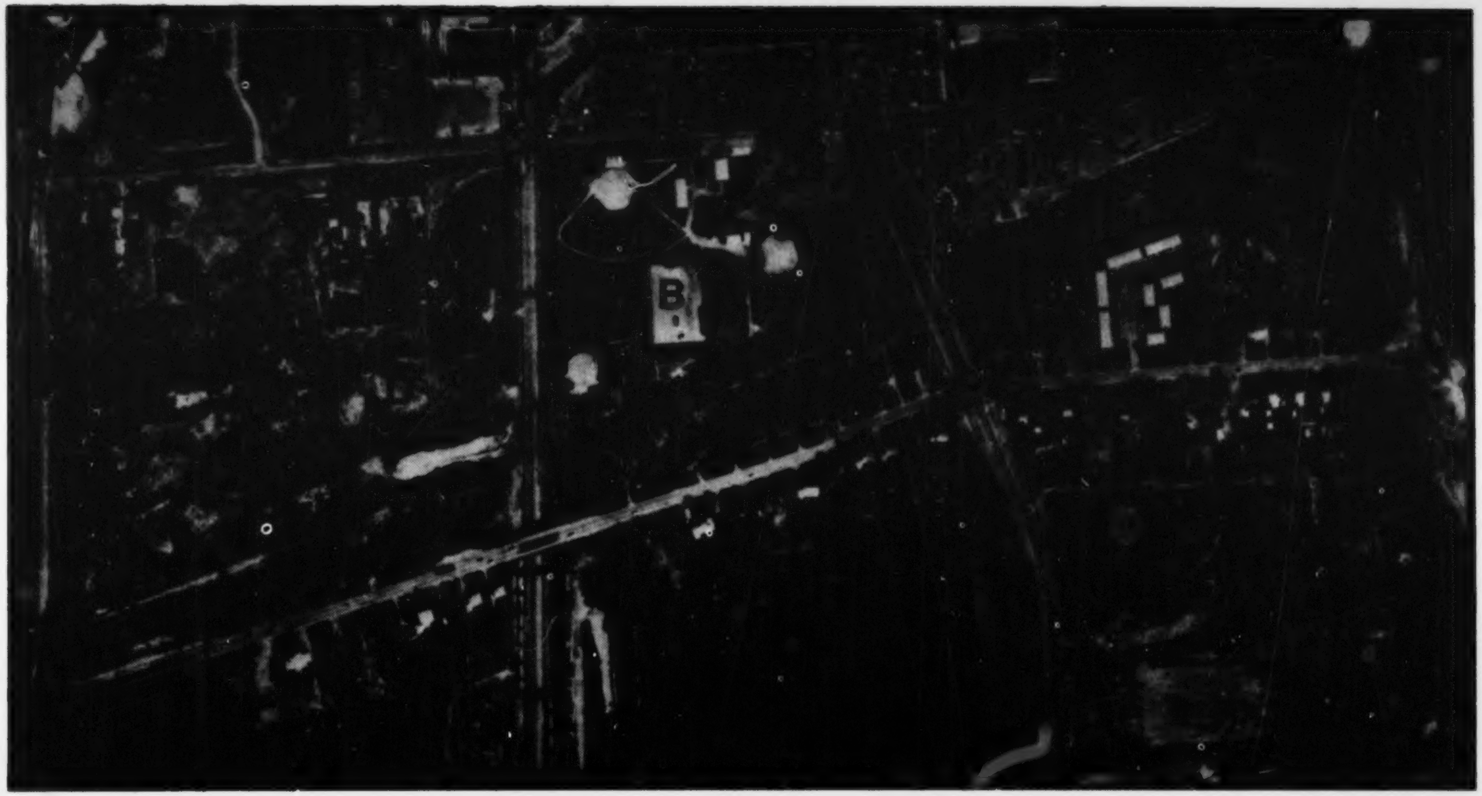


Figure 2-2. An orthophotomap would appear similar to the above figure, which shows the detail visible on these sheets: (A) apartments and residential area; (B) athletic complex; (C) parking lot; (D) active landfill. A maximum site boundary is drawn on the map which includes B, C, and D. B and C were active in the 1950's and 1960's and have subsequently been covered by a parking lot and ball fields.

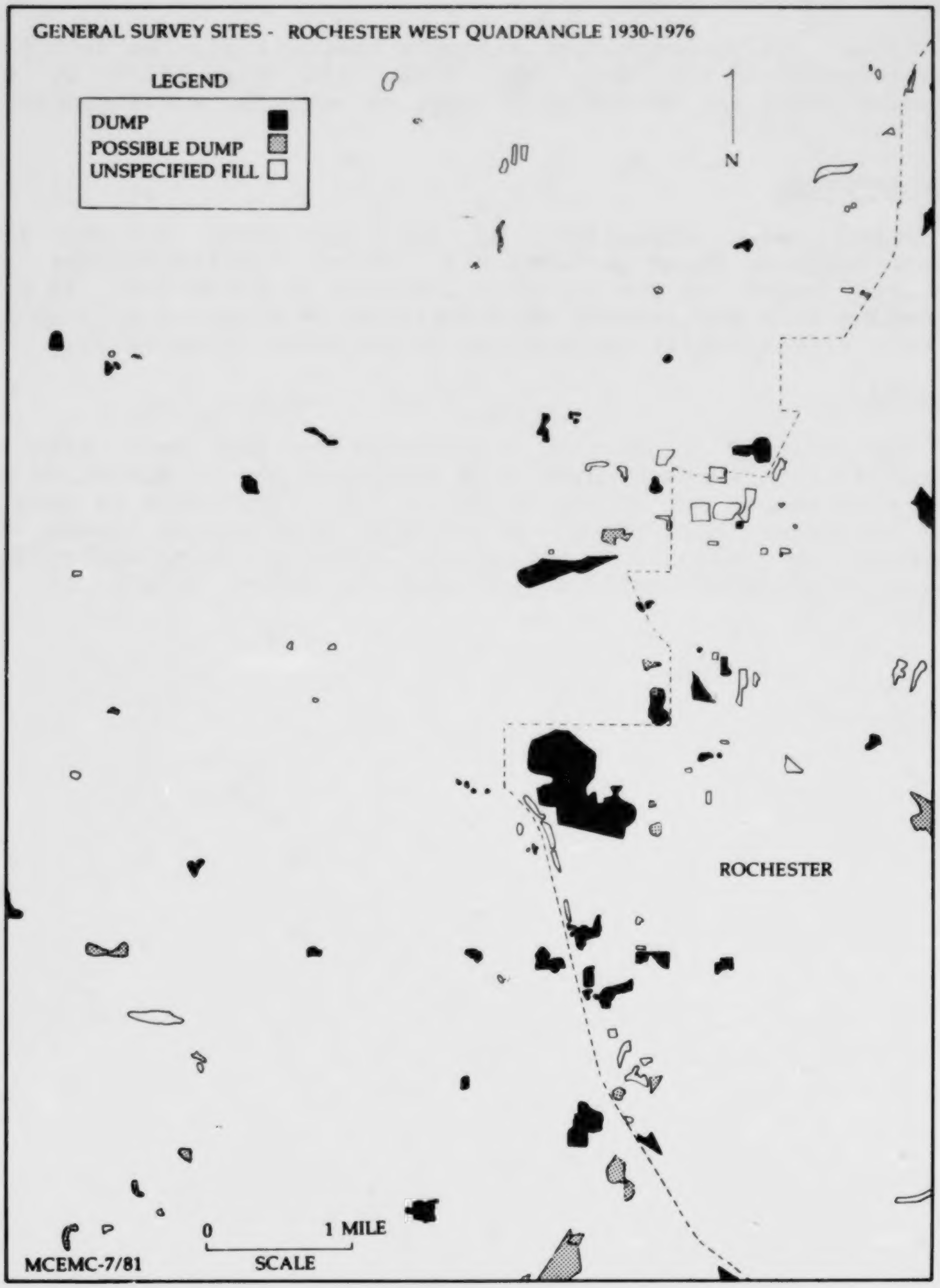

GENERAL SURVEY SITES - ROCHESTER WEST QUADRANGLE 1930-1976
LEGEND
DUMP ■
POSSIBLE DUMP ▨
UNSPECIFIED FILL ☐
N
ROCHESTER
0
1 MILE
SCALE
MCEMC-7/81

Figure 2-3. Inventory of sites: Rochester West Quadrangle.

CLASSIFICATION OF SITES

After the photointerpretation is complete and the data have been recorded on the SAR, the sites are classified by the research assistant according to type of activity and surrounding land use.

Site Activity

Sites are classified by activity using one of five classifications found in Table 2-2. These classifications are assigned based on the criteria outlined in Table 2-1. In many instances this preliminary determination of activity will change as more site-specific information is gathered (Chapter 3).

Land Use

The initial land use classification for each site is assigned at this stage based on a review of the information on the most recent aerial photographs. The information is used to rank the sites for impact on nearby populations using the criteria in Table 2-3. Land use classifications are refined during field investigations conducted at later stages of the study.

TABLE 2-2. SITE ACTIVITY CATEGORIES

D - Identifiable Dump/Landfill

Sites where information on dumping or landfilling activity is known from public records, interviews with government or industry officials, the public call-in campaign, industrial surveys, or where dumping activity is clearly evident on aerial photographs. This category includes sites with conspicuous drum storage.

P - Possible Dump/Landfill

Sites where filling activity is evident but there has been no confirmation as to whether or not dumping occurred. However, based on the location of the site and peripheral land use, it would appear that dumping could have occurred. Sites located adjacent to industrial or commercial activities, maintenance areas, large construction sites, and public facilities such as sewage treatment plants and incinerators should be evaluated as possible dumps.

U - Unspecified Filling

Sites that are apparent either as recent surface disturbances or topographic changes that were not present on earlier photographs. Sites that are obviously clean fill for construction purposes are not included in this category nor are they annotated. (Such sites may be identified by the relatively rapid completion of activity followed by the appearance of a highway, new building or structure on more recent photographs.)

L - Lagoons, Surface Impoundments, or Bermed Pits

Potential liquid waste disposal areas that are either suggested by associated activity on the photographs or are known to have existed. Standing water in borrow pits or quarries is not generally placed in this category unless associated with dumping.

J - Auto Junkyards, Waste Piles, and Salvage Areas

Areas identified on the photos as having an unusually high volume of junked autos, appliances, or similar material should be noted. Such sites may contain significant surface disposal or spills of oil, transmission and hydraulic fluids, or solvents.

TABLE 2-3. LAND USE CLASSIFICATION

	Land Use Activity
.01	24-hour occupancy* on or within 100 feet of site
.02	Part-time occupancy+ on or within 100 feet of site
.03	24-hour occupancy from 100 to 1000 feet of site
.04	part-time occupancy from 100 to 1000 feet of site
.05	24-hour occupancy from 1000 to 2500 feet of site
.06	part-time occupancy from 1000 to 2500 feet of site

* residences, hospitals, nursing homes

+ industrial and commercial facilities

After the photointerpretation is complete, site boundaries will exist for most sites identified through the call-in campaign, historic records, and government hazardous waste reports. In some cases the call-in information will not be verified by photo interpretation or agency records. It will then have to be concluded that the information was in error, was for a site that was incorrectly located by the caller, or was for a site used during a period when no aerial photographs were taken. The call-in information that is not confirmed should be filed in case additional documentation is obtained at a later date which verifies dumping activity

SUMMARY AND CONCLUSIONS

This chapter describes a method of inventorying active and inactive dump/landfill sites. The criteria recommended for distinguishing between waste disposal and fill areas should be carefully applied by a photointerpreter with experience in waste disposal and engineering techniques to avoid incorrectly identifying the sites. Since it is difficult to determine site contents from photointerpretation, supplemental information from other sources must be gathered. This will help clarify and verify the activity noted on the photos. These methods are described in Chapter 3.

CHAPTER 3

SITE CHARACTERIZATION

INTRODUCTION

After the inventory phase is complete, a variety of sites will have been identified. Some will obviously be dumps/landfills, but there will be many possible dumps/landfills and unspecified fills for which supplemental informaton will be required in order to determine if wastes were disposed of at these locations. This chapter describes various resources that can be used to obtain additional information for development of a more detailed profile of site activity, and to evaluate potential impacts.

The objectives of developing site-specific information are:

1. to verify and clarify activity noted on the aerial photographs (which of the possible dumps/landfills and unspecified fills were actually used for dumping);

2. to produce more detailed site information on identified dumps/landfills (owners, users, permits, contents); and

3. to provide the information necessary to rank the sites for potential impact on drinking water supplies and people living/working on or near the dumps.

ORGANIZATION

While the overall inventory phase is organized by USGS topographic maps, the site characterization phase should be organized by municipality since one of the activities involves interviewing local officials, and the information on site locations will ultimately be published by municipality. This approach may require completion of the inventory for several contiguous topographic maps prior to site-specific investigation since USGS maps do not conform to municipal boundaries.

Once the inventory for a municipality is complete, a composite of all sites within the municipality should be prepared. Site locations for dumps/landfills, possible dumps/landfills, unspecified fills, lagoons, and junkyards are transferred from the orthophotomaps (1"=200') to an intermediate scale (1"=800' to 1"=1200') municipal subdivision map. Both the municipal map and the site boundaries prepared on the orthophotomaps are shown to city and town officials during the search for site-specific information. The municipal maps can also be compared with other local resource maps (wetlands, natural drainage, woodlots, water service areas) to obtain information on environmental and social impacts.

The SAR initiated during the inventory phase is used extensively during this phase to record detailed informaton on individual sites. The use of this form is discussed in detail in Appendix E.

The preparation of maps and the compilation of additional information from interviews and other sources is performed by the research assistant. The site rankings for impact on drinking water supplies are performed by the geologist and the research assistant.

SITE VERIFICATION/CLARIFICATION

Because waste disposal cannot always be distinguished from clean fill on the aerial photographs, it is necessary to verify site activity, particularly for sites in the possible dump/landfill and unspecified fill categories. There are two primary sources used for this purpose:

- interviews with municipal, industrial, and public works officials; and
- public agency records and files

Information from these sources can (a) help identify the inventoried sites that were actually used for waste disposal, those containing clean fill, and those requiring further investigation; and (b) provide more detailed information on known dumps/landfills.

Interviews

The interview process should begin with a senior administrative official of the municipality. It is important to inform this person of the study's goals and findings and of the need to identify and contact other knowledgeable people for additional site information. In addition, this individual may be able to assign one municipal employee to work with the study staff in researching records.

The interviewer is looking for maps, records, and permits, as well as information that may be remembered by longtime employees. The fourth page of the SAR contains a checklist of municipal officials that should be contacted. Personnel who work with records, as well as those who perform field inspections, should be sought out. In addition, members of town boards, including planning, zoning, and/or environmental boards who conduct field inspections, may also be a valuable resource. The municipal historian should not be overlooked. In Monroe County, the most useful contacts were with town supervisors, building inspectors, and those who work with town records.

Town officials and employees respond most effectively when shown both the municipal subdivision maps and the orthophotomaps for individual sites. Preparation of these materials in advance of the interview is advisable. All information obtained from interviews should be recorded on the SAR. More complete information can be obtained during these interviews if the research assistant visits all sites first. The land use ranking assigned during the site identification stage can be verified or modified at this time (Table 2-3). Additional valuable information on the area is often obtained during these visits including identification of adjacent industries, visual evidence of unpermitted waste disposal, the presence of leachate seeps, and the adequacy of site coverage.

In assessing information on possible dumps/landfills and unspecified fills obtained during interviews it is important to obtain information from other sources before eliminating sites identified by local officials as uncontaminated. Claims that no waste was disposed at a specific location should be corroborated since municipal officials may simply not be aware of past waste disposal activity.

The maps should also be reviewed with personnel from local industrial organizations, utility companies, and county public works agencies to identify sites used for industrial waste disposal. Interviews can then be held with specific industrial and utility company personnel to confirm the activity.

Agency Files

Agency files and reports checked during the site identification stage should be reviewed now that specific site boundaries have been delineated. These reports may confirm waste disposal activity and provide information on site contents, owners, and operators. Local health department files often contain inspection reports on both permitted and unpermitted waste disposal activities of the past 10 to 20 years. Files in solid waste offices of state departments may also produce valuable documentation of disposal activity. General reports on disposal practices, both historic and recent, may be located in other agency files. Industrial inventories conducted for other purposes, such as pretreatment programs, provide information on waste streams for specific industries. There are also an increasing number of federal and state reports on hazardous waste site locations, contents, operators and owners. The information in these documents should be verified by additional research since the data is not always complete or accurate.

In Monroe County, health department inspection reports and permits were located that allowed the reclassification of some possible dumps/landfills and unspecified fills. New York State DEC files provided information on permitted sites and a survey of disposal practices for major industries. A computer listing of all city building permits, filed by address and extending back to the early 1900's, was located for the City of Rochester. This listing includes information on permits to construct storage tanks and other disposal facilities.

DETAILED INFORMATION ON IDENTIFIED DUMP/LANDFILL SITES

In addition to clarifying activity noted at possible dump/landfill and unspecified fill sites, the interviews with local officials and the search of agency files can provide more detailed information on known dump/landfill sites. Town officials can often identify owners and users; occasionally they can provide information on site contents, periods of operation, and disposal practices. Agency records may contain information on permits issued or correspondence indicating site contents.

Once waste disposal activity is confirmed, interviews with officials from industries located on or adjacent to sites may produce valuable information. The interviewer should have the orthophotomap as well as the relevant years of aerial photography available during the interview. Plant managers, environmental control personnel, and long-time employees should be asked to clarify any activities noted on the photos, including waste disposal locations, other related activites (e.g., sand and gravel extraction), site owners, users, contents, and solid waste management practices employed. Not all industries will be willing to give complete or accurate information; data should be cross-checked through other sources. All information should be recorded on the SAR.

In addition to interviews with local officials, records in agency files, and interviews with industrial personnel, sources that should be consulted for site information include street directories, historic maps, business directories, deeds, and tax records.

Street Directories

One clue to the types of activities observed on the photos can be obtained by identifying industries operating on adjacent properties during the period of observed activity. Although it may eventually be necessary to research deed information on past site ownership, particularly if enforcement action is anticipated, an initial identification of present or past industries may be more helpful. This is most easily accomplished by consulting city or suburban street directories (see Bibliography) for the years that activity was noted. This is a simpler and more useful approach than researching deeds, which sometimes reveal the owners but not the users of a site during the period of concern.

Historic Maps

There are two types of historic maps that provide valuable clues to previous ownership and site activity.

Historic plat book maps found in county clerks' offices and public libraries contain property line boundaries and owners.

Fire insurance maps contain historic information on building locations, design details, and types of businesses dating as far back as the 1860's. These maps were prepared by the Sanborn Fire Insurance Company to show the location and flammability of buildings for fire insurance purposes. Prepared at a scale of 1"=50', they provide excellent site detail on structures and occupants. They also contain information on natural features, such as wetlands and gorges, that could have been used for dumping. The maps can be found in the Library of Congress as well as public and college libraries. For a complete listing of all maps and locations consult The Union List of Sanborn Fire Insurance Maps Held in the United States and Canada (9). For a more complete discussion of these maps, see Mudrak (10).

Business Directories

Business directories contain information on types of businesses and industries, locations, and the nature of the products and services offered. There are also directories of manufacturing industries published by either state or municipal agencies that provide basic information on industries by Standard Industrial Code (SIC) (see Bibliography). These documents provide clues about the type of waste produced by industries on or adjacent to a site.

Deeds and Tax Records

Deeds and tax records can be searched to locate information on past and current site owners. Searches for past owners are usually time-consuming and would be most expeditiously and accurately carried out by an attorney or researcher familiar with deed information. Current owners should be identified for each confirmed dump so that they can be notified of the presence of waste disposed on the property.

Environmental Data

Environmental atlases and natural resource inventories contain valuable information on the location of important environmental features such as wetlands, drainageways, streams, ponds, subsurface geology, and soil characteristics. This information is useful in assessing the potential impact of uncontrolled sites on surrounding areas.

IDENTIFICATION OF CONFIRMED DUMPS/LANDFILLS

Once the interviews and review of agency files are complete, a list of confirmed waste disposal sites can be developed. These sites are mapped on mylar overlaid on the appropriate USGS topographic sheet. These maps are then referred to the project geologist for geologic ranking of sites (Chapter 5). A search for drinking water supplies within specified distances is also conducted.

WATER SUPPLY IMPACT EVALUATION

There are numerous pathways of exposure between contaminants from an uncontrolled site and human receptors (drinking water, ambient air, food, soil). Drinking water containing toxic chemicals often has the greatest potential for directly impacting human health and is a pathway that can be most easily documented with available records. Therefore it is important to identify public and private drinking water supplies located close to uncontrolled sites.

There are three types of drinking water sources:

1. public water supply system: a system for the provision of piped water to the public for human consumption. Such a system has at least 15 service connections or regularly services 25 or more individuals;

2. private water supply system: a system which provides piped water for human consumption to less than 25 individuals (nonresidents) on a daily basis at least 60 days of the year. Facilities include restaurants, golf courses, camps, and churches; and

3. individual system: a water well (generally) that serves a single residence.

Public and private water supply systems can have either surface or groundwater as a source. In Monroe County only the location of groundwater sources (wells) were researched since the one downstream surface water intake location is in Lake Ontario beyond the immediate impact of any single site. The selected distances of concern from the boundary of a site were 1000 feet for wells serving single residences and one-half mile for public and private water supplies. Under unique geologic conditions public wells from one-half to three miles and individual wells from 1000 feet to one mile were independently evaluated.

Locating Drinking Water Supplies from Groundwater Sources

The locations of public and private water supply systems can be obtained from the local health department which has responsibility for testing these sources on a regular basis. The utility providing the service and the state agency in charge of allocating groundwater resources can also identify locations.

Information on wells serving single residences can be more difficult to obtain, particularly in counties that do not maintain a comprehensive list of individual well owners. The existence of individual wells in areas not served by public water supplies can be assumed. The presence of these wells can be determined by checking maps delineating the boundaries of the municipal water supply system.

Availability of public water does not necessarily mean that all residences are connected to the system, however. A search must be made for homes using water wells within 1000 feet of each site within a water supply district. This is done by comparing the street numbers of homes and businesses with water billing records. The large-scale site orthophotomaps are the best base on which to draw the 1000 foot boundary and to record house numbers and water well locations. When an address is found that does not receive a bill, it is assumed that a private well is in use. These locations should be field checked to verify that the address is not vacant property or part of a multiple dwelling unit. (Water bills are usually sent to only one resident or to the owner of multiple units.) The actual existence and use of the wells will have to be confirmed by the homeowner after notification by the Health Department (Chapter 6).

Ranking of Sites and Water Supplies

After a search has been made for nearby drinking water intake locations, all sites are ranked for proximity to drinking water supplies (Table 3-1, Stage 1). Sites that receive a ranking of .01 have supplies within the specified distances. Not all supplies will be impacted equally, however; each must be separately evaluated and ranked for contamination potential (Table 3-1, Stage 2). This is done by the hydrogeologist who considers both geologic conditions and surface features (Chapter 5). A site visit is important at this stage to assess special conditions not evident on maps and aerial photographs that could exacerbate or ameliorate the contamination of water supplies.

Response

After the geologist ranks the water supplies for contamination potential, public and private water supplies found to be in the path of a potential leachate plume should be referred immediately to the local health department for follow-up action.

For individual well owners within the 1000 foot boundary, one of two actions is possible:

1. testing of the well by either the homeowner, local health department, state conservation department, EPA, or the dump site owner; or
2. notification of the homeowner of the potential hazard and recommendation of connection to a public water supply or use of bottled water if public supplies are not available.

The actions chosen will be determined by local policy makers based on the availability of funds for testing, the potential severity of the problem, and whether or not a site owner, operator, or user can be identified.

SUMMARY AND CONCLUSIONS

Once sites have been initially identified, it is important to verify the type of activity noted on the aerial photographs. This is done to determine which sites in the possible dump/landfill and unspecified fill categories were actually used for waste disposal. Interviews with municipal/public works officials and industry representatives and a search of agency records are the best means of confirming waste disposal

Table 3-1. CRITERIA FOR RANKING DRINKING WATER SUPPLIES

Stage 1.	Site Proximity to Drinking Water Supplies
Rank	Proximity Category
.01	Site has active water wells serving a single residence within 1,000 feet, or a public/private water supply system within one-half mile (or up to three miles with geologic conditions indicating potential contamination).
.02	Single well or public/private water supply system within the zone of influence described above but not in use.
.00	No single well or public/private water supply source within zone of influence described in .01 above.
Stage 2.	**Water Supply Contamination Potential**
Rank	Hydraulic Gradient Category
.01.	Single well or public/private water supply system downgradient of site.
.02.	Single well or public/private water supply system not downgradient of site.

activity. Local residents are contacted only after other sources have been reviewed.

Once waste disposal locations are confirmed, a careful search for private and public water supplies within specified distances of the sites is undertaken.

For both the site characterization and water supply location phases, it is important to contact individuals with detailed knowledge of municipal records and personnel who have worked in the municipality for a number of years. Employees or board members that regularly conduct field inspections often can provide valuable information.

Completion of the site characterization work described in this chapter concludes the site inventory phase. The work should be integrated with the geologic evaluation described in Chapters 4 and 5.

CHAPTER 4

GEOLOGIC ANALYSIS

INTRODUCTION

At the same time that the inventory of sites is being conducted, a general geologic analysis of the entire region under study should be done so that sites can be evaluated and ranked according to potential impact on nearby residents and surface and groundwater drinking water supplies. This analysis also provides useful information for site-specific studies conducted during later phases of the project.

The important factors examined in the general hydrogeologic analysis are those which directly influence the production, containment, attenuation, or migration of leachate. These generally involve the groundwater system, the soil or rock permeability, and the structures within the overburden or rock that control either the direction of movement, rate of movement, or local concentrations of fluids. In most cases, landfills or old dumps will be found in unconsolidated soils or overburden, but occasionally the character of the local bedrock is also significant. The critical factors must be evaluated within the particular region under study.

When assessing waste disposal sites that were operated prior to the late 1970's, it should be assumed that wastes were placed primarily in natural or man-made depressions without utilization of sophisticated preparation or containment techniques. Thus, the structures and properties of the overburden and rock formations should be assumed to control the natural migration of fluids and groundwater on or adjacent to the site.

This chapter describes the general types of geologic information needed, as well as sources, organization, and utilization. The procedure for site ranking based on the analysis of this information is described in Chapter 5.

The hydrogeologic aspects of this project involve a comprehensive review of published literature, the location and collection of unpublished data, development of both regional and site-specific groundwater models, and an integrated analysis of the geologic/historic information preserved on aerial photographs. The detail and accuracy of the geologic interpretations will depend on the quality and types of available information, as well as on the complexity and variability of surficial and bedrock geology.

The experience gained during the Monroe County study indicates that a year should be allotted for the location, collection, and mapping of data from unpublished sources (e.g., engineering borings). This is because a substantial portion of this data must be identified and gathered through personal contacts, which develop gradually, and from exhaustive searches through agency files and unpublished records.

Because there may be valuable geological information contained on aerial photography, it is recommended that the geologic and aerial photographic analysis be closely coordinated and integrated. In particular, aerial photographs that predate extensive urbanization may contain valuable clues to the near surface geology or groundwater conditions in areas where extensive excavation and landfilling are subsequently noted.

A general geologic analysis serves the following functions:

1. it provides a broad framework for understanding the general hydrologic, stratigraphic, and soil conditions in the region that are important in the production, containment, attenuation, or migration of contaminated groundwater or leachate at or adjacent to potential sites;

2. it provides a consistent framework with which to rank and compare the general hydrogeologic characteristics of sites for which specific information is lacking for the purpose of:

   a. determining the potential impact on people;

   b. furnishing local officials a consistent, scientific basis upon which to allocate scarce resources for clean-up efforts; and

   c. allowing municipalities to more effectively meet federal (CERCLA and RCRA) and state regulatory requirements;

3. it allows the development of more detailed models of the hydrogeologic conditions at specific sites, especially where some limited subsurface information (e.g., outcrops, borings) is already available or might be safely extrapolated from information available at nearby locations. This should include, where possible, information on the water table gradient and groundwater velocity and

the geologic conditions controlling these parameters;

4. it reduces the expense of costly or randomly designed drilling or exploration programs by utilizing presently available information on subsurface conditions; and

5. it provides an understanding of the basic geology that permits focusing of studies or limited funds on those areas where excavation/disposal activities might have been concentrated (e.g., abandoned borrow pits).

ORGANIZATION OF THE GEOLOGIC STUDY

The geologic portion of the study should be performed by a hydrogeologist associated with the project and familiar with the area. This individual should direct the collection of basic geologic information, prepare geologic maps, and analyze the information (including aerial photographs) for specific sites.

The quality of hydrogeologic information will vary from state to state and region to region. The hydrogeologist will have to locate published and unpublished geologic and engineering documents, evaluate the quality of the data, and identify information gaps. From this information a preliminary hydrogeologic model for the area can be developed that will enable the hydrogeologist to determine how the existing information should be used and the most practical formats into which the different data sets should be converted. This might vary from regional groundwater contour maps to detailed hydrogeologic cross section diagrams of individual sites. In some regions, published hydrogeologic or geologic maps may be well suited to the needs of a site evaluation study and only need minor updating with new information and conversion to a convenient scale. After the geologic information is gathered and mapped, it is used by the hydrogeologist to rank the sites.

The three basic steps in developing a geologic information base are:

1. inventory and collection of existing geologic data;

2. compilation or modification of regional, quadrangle, or site specific geologic maps or profiles; and

3. development of hydrogeologic models.

INVENTORY AND COLLECTION OF THE DATA BASE

There are numerous documents or records, published and unpublished, that contain geologic information useful in the construction of hydrogeologic models. A general listing of these sources includes:

- USGS publications
- State Geological Survey publications
- Geologic maps and reports in professional journals
- Bulletins or proceedings of local scientific societies or associations
- USDA county soil maps
- Topographic maps
- Aerial photographs
- Engineering data and reports
- Miscellaneous information in unpublished or limited distribution form

Because the variety of materials available from some of these sources may not be familiar to the reader, the individual categories are described in the following section in greater detail.

United States Geological Survey Publications

The Geological Survey regularly publishes Bulletins, Water Supply Papers, Professional Papers, and individual State or Geologic Quadrangle maps. A significant amount of material is only available for limited distribution as "open file" reports (Open File Services Section, USGS) or through the National Technical Information Service. These two latter categories include much information of environmental interest. Anyone pursuing these sources should consult at least one issue of the free monthly listing of "New Publications of the Geological Survey" (2) that describes more fully the types of materials available and ordering information. Separate state lists of geologic and water supply reports or maps are available free from the USGS.

Of special interest are the Miscellaneous Investigations Series geologic maps prepared for 7-1/2 or 15 minute quadrangles or special geographic regions. The maps are prepared in alphabetical series for each quadrangle or region and may include such parameters as:

- Depth to water in wells
- Groundwater velocities
- Recoverable groundwater resources
- Vegetation types
- Sand and gravel or mineral resources

- Land subsidence
- Slope
- Dissolved solids in groundwater
- Chemical quality of groundwater
- Land use classification
- Thickness of alluvial deposits
- Land status
- Water budget components
- Aquifer thicknesses

Generally several maps are completed for each quadrangle, depending on the purpose, scope, and data available for each study. Good examples of such maps can be seen in published USGS map series I-856 (Denver Urban Corridor Area), I-844 (Tucson Area), I-1074 (Connecticut Valley Urban Area) and I-766 (Sugar House Quadrangle, Salt Lake County, Utah). A general index of all USGS maps through 1977 has been prepared by Androit (11) and newer maps appear in the monthly listing mentioned above. Free geologic map indices are available on a state by state basis from the USGS.

State Geological Survey Publications

All states have either geological surveys or water resources divisions that publish formal or informal reports of geological significance, such as well drilling logs. The variety of types of information available is very different from state to state and often reflects differences in major industries (mining, oil, agriculture) or natural resource management policies. Direct contact with such state agencies is the best way to find out about current published information or files of data that may have been maintained in the past.

Information within individual states may be collected and maintained by regional offices of agencies such as the U.S. Forest Service or the U.S. Bureau of Land Management. Increasingly these agencies are being required to produce reports relating to land management problems that are not formally published but may contain up-to-date and unique information on geology and groundwater.

Geologic Maps and Reports in Professional Journals

Although fewer geologic maps are being published in most nongovernmental publications, the geology of many local areas is contained in the past issues of journals such as the Geological Society of America Bulletin. These sources are so diverse and randomly distributed throughout the professional literature that a knowledgeable person should be consulted to conduct a search for such information. A local university geology department or library is a good place to begin such a search.

Local Scientific Societies or Associations

These local or regional organizations irregularly publish reports describing the local geology, often in the form of field trip guidebooks compiled for scientific meetings or as symposia volumes. Many are called "state geologic societies" but have no official ties to state geological surveys. An attempt should be made to contact or inventory all such groups or organizations for information or suggestions.

USDA County Soil Maps

The USDA has published one or more editions of county soil maps at scales of 1:24,000 or larger for most counties where agriculture has been a significant activity. These maps usually describe only the qualities of the top few feet of soil. However, there is usually a direct relationship between the surficial soils and the deeper overburden or bedrock geology. Many of these maps and reports contain geologic descriptions of the materials or geologic events that influence soil properties and development. The newer series of reports are being prepared on an aerial photographic base and contain some detailed charts of the engineering properties of the different soil types.

The older soil maps are important sources of information for areas where urbanization has since obscured the surficial geology. These same maps often have special designations for "dumps," "made land," and "pits and quarries" that were active or inventoried at the time of the survey. Also the local county Soil Conservation Service office that was involved in the production of the county soil maps may have retained the original field copies of the aerial photographs that were used to construct the published maps.

Topographic Maps

Although topographic maps are produced by the USGS and are used for general mapping throughout this project, they are discussed separately here with regard to their value as geologic tools. To a geologist, the shape of the earth's surface contains a record of the processes that have shaped it. In many instances a reasonably accurate estimate of soil textures or related information may be inferred from a careful study of good topographic maps when used in conjunction with aerial photographs. Because topographic maps are regularly updated from aerial photographs or topographic surveys, they contain a reasonably detailed record of land use changes and topographic modifications. Thus, older editions should be used for geomorphologic interpretations, whereas newer editions reflect land use activities including landfills, dumps, sand and gravel extraction, or mining activity. Out-of-print editions of old topographic maps are available by state on microfilm from the National Cartographic Information Center (NCIC).

Aerial Photographs

While aerial photographs are used for other portions of the study, they also contain valuable geologic information. When viewed stereographically, aerial photographs, especially older photographs of urbanized areas, provide the next best alternative to field surveys. The subtle features seen on aerial photographs provide more detailed clues to the geologic events and soil textures than do topographic maps. Where no other source of information is available, a photogeologic analysis may provide the only type of data to fill in the gaps between existing maps, reports, and borings. Aerial photographs are especially useful in former glacial regions where geologic processes often provide direct information concerning landform genesis and overburden character. One example of this is the appearance on aerial photographs of easily recognizable glacial meltwater channels. These features usually contain sand and gravel resources. After the resources are extracted, these areas are frequently used for dumping activity. These and other glacial landforms are found throughout the United States north of the Missouri and Ohio Rivers and in New York and New England.

Engineering Data and Reports

This information, gathered by government agencies or private companies, is generally related to construction projects and is in the form of soil testing data and boring logs. The specific sources vary considerably, depending on local engineering practices or construction problems common to particular regions of the country. The general sources of such information are:

- Local, state, or federal highway agencies and contractors
- Town, village, or county construction and maintenance projects
- Utility companies (e.g., for powerlines and power plants)
- Firms or agencies responsible for canals, pipelines, railroads, airfields, and public buildings
- Drilling, soil testing, and engineering consulting firms
- Architectural firms
- Oil, gas, and water well drillers (some states require public records of these activities)
- Sewer and water district agencies
- Quarry, tunnelling, or mining companies
- Industrial firms

Geologic consultants or field geologists within various regions of the United States are generally familiar with such sources of information. Some of this information may not be released by private companies or individuals. However, for a survey such as this, the development of personal contacts at the various types of firms or agencies listed above may result in significant cooperation in securing information that is in the public interest. In some cases it may be necessary to document the location of specific sites so that engineering boring logs can be efficiently obtained from inactive files.

Miscellaneous Information in Unpublished or Limited Distribution Form

Government agencies or corporations may have unique collections of information of geologic importance in specific areas of the country. It is difficult to list or even surmise what all these sources might be, but some attempt should be made to inventory unique resources within each region. These might include reports on special projects by the U.S. Army Corps of Engineers, the U.S. Bureau of Mines, state environmental agencies, departments of health, or the U.S. Bureau of Reclamation. Regional 208 water quality management agencies map water resources, industries with effluents, and waste disposal activities. These are classified by drainage basins.

Only a short list of potential sources has been presented to provide some illustration of the different types of activities that characterize different regions of the country. Many federal, state, and local agencies maintain or periodically contract for aerial photographic surveys for special projects or studies.

The cost of time invested in a careful search for unpublished engineering records and subsurface data can be more than compensated for by the elimination or reduction of costs associated with fieldwork or exploratory drilling. The successful location of detailed subsurface geologic information on even a few critical sites can significantly reduce costs and provide a greater measure of confidence for extrapolation of subsurface hydrogeologic conditions to less well documented sites.

The initial survey of available sources of geologic information should begin with a thorough review of published and open-file reports of the USGS, state geological surveys, local or state geologic societies, university geology departments and libraries, and firms holding engineering data. From this general review of information a more detailed approach for locating specific or missing information can be developed.

DEVELOPMENT OF HYDROGEOLOGIC MODELS

The purpose of a geologic analysis of waste disposal sites is to understand how groundwater or leachate may migrate within, beneath, or adjacent to the sites. This is generally achieved by analyzing water table data and information on the textures, structures, and permeabilities of the overburden sediments and the bedrock formations. When the near-surface geology consists of several heterogeneous rock or overburden formations there is usually a predictable relationship between the properties of the geologic materials and the movement of fluids through them. Where sufficient data is available to estimate the local groundwater depth and gradient, the likelihood of contaminant migration through typical sediments or bedrock formations can be estimated either for the region or for individual sites.

A hydrogeologic model is constructed by locating existing maps or plotting all relevant geologic and groundwater data on contour maps so that both the areal and vertical variations of important parameters (e.g., depth to groundwater) can be compared. Groundwater depth and gradient, and estimated soil or rock type and permeability are the main considerations. A more detailed discussion of all the common variables is included in the section explaining the Geologic Ranking Sheet (pp. 60-61).

If the existing geologic map or groundwater data coverage for a region is extensive and of sufficiently good quality, modeling of hydrogeologic conditions near most suspected sites may be relatively straightforward. This is more likely to be true in the southern nonglaciated portions of the United States. The boundary of continental glaciation conforms approximately to the line formed by the Missouri and Ohio Rivers extended eastward through northern Pennsylvania and northern New Jersey. Because the sedimentary deposits left by the Pleistocene ice sheets north of this boundary are generally very heterogeneous with irregular surface relief, it is more difficult to extrapolate hydrogeologic models of groundwater flow in these glaciated areas. Unusual groundwater flow conditions can also be found in regions underlain by limestone bedrock containing irregular solution channels produced when groundwater enlarges natural joints or openings in the rocks. In such regions surface streams may disappear underground and groundwater conditions are often unpredictable.

Because of the variety of geologic conditions that are found throughout the United States, it is recommended that the planning and implementation of the hydrogeologic analyses required for this survey be carried out or closely supervised by a geologist familiar with the local geology and experienced in hydrogeologic analysis.

In areas where little subsurface geologic data is available, a thorough knowledge of the geologic history pertaining to the origin of the overburden, coupled with stereographic analyses of diagnostic landforms, can enable a geologist to extrapolate or approximate the hydrogeology of a site.

The project geologist should develop either regional or site specific models based on the geologic complexity or unique conditions in each project area. Some suggestions and examples based on the Monroe County study are included in the next section and in the case history discussed in Appendix J.

COMPILATION OR MODIFICATION OF REGIONAL, QUADRANGLE, AND SITE SPECIFIC GEOLOGIC MAPS OR PROFILES

It may be necessary to compile or revise different types of geologic maps for use in hydrogeologic site analyses for the following reasons: (a) detailed surficial geology and groundwater maps have not been prepared for all of the United States at scales of 1:24,000 or greater, (b) many geologic maps do not show the distribution of unconsolidated overburden sediments, (c) newer information may have to be added, and (d) existing maps may need to be redrawn at the same scale as other project maps or overlays.

One advantage of constructing general maps for the entire project region is that significant new information is likely to be located. Integration of all available information will produce a more comprehensive understanding of the regional geology and is likely to improve the individual site hydrogeologic analyses. However, the practicality of such an undertaking should be weighed against the costs and time involved for the estimated number of sites in a region.

The different types of geologic maps that could be compiled include all of those previously listed under the category of USGS Miscellaneous Investigations Maps, depending upon the scope of each study and the problems that are identified as being significant within the region. In general, three types of maps would be most useful (Figures 4-1, 4-2, 4-3):

- a map showing the shape and elevation of the bedrock surface, including any formations that are considered to be important in the analysis of groundwater movement (Figure 4-1);

- a map showing the surface of the groundwater table in the overburden sediments and/or bedrock. In areas of more complex hydrology such basic maps may only be simplified representations of actual groundwater conditions. Such a map might also

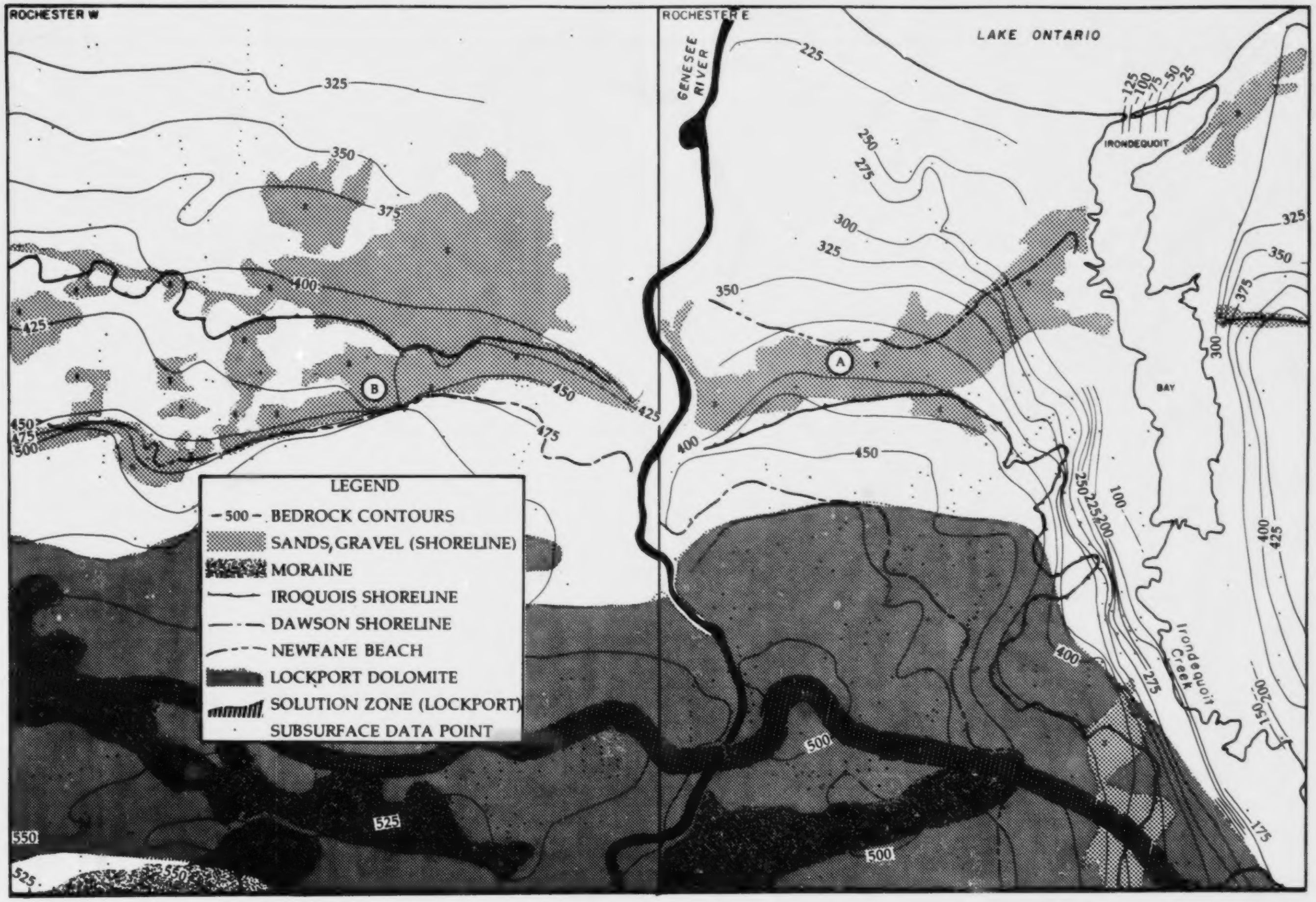

ROCHESTER W
ROCHESTER E
LAKE ONTARIO
GENESEE RIVER
IRONDEQUOIT
BAY
Irondequoit Creek
A
B
325
350
375
400
425
450
475
500
525
550
225
250
275
300
125
100
75
50
25
200
175
150
LEGEND
-500- BEDROCK CONTOURS
SANDS, GRAVEL (SHORELINE)
MORAINE
IROQUOIS SHORELINE
DAWSON SHORELINE
NEWFANE BEACH
LOCKPORT DOLOMITE
SOLUTION ZONE (LOCKPORT)
SUBSURFACE DATA POINT

Figure 4-1. A portion of the Bedrock Surface Map (with selected surficial geology) prepared for Monroe County, N.Y. Contour interval 25 feet.

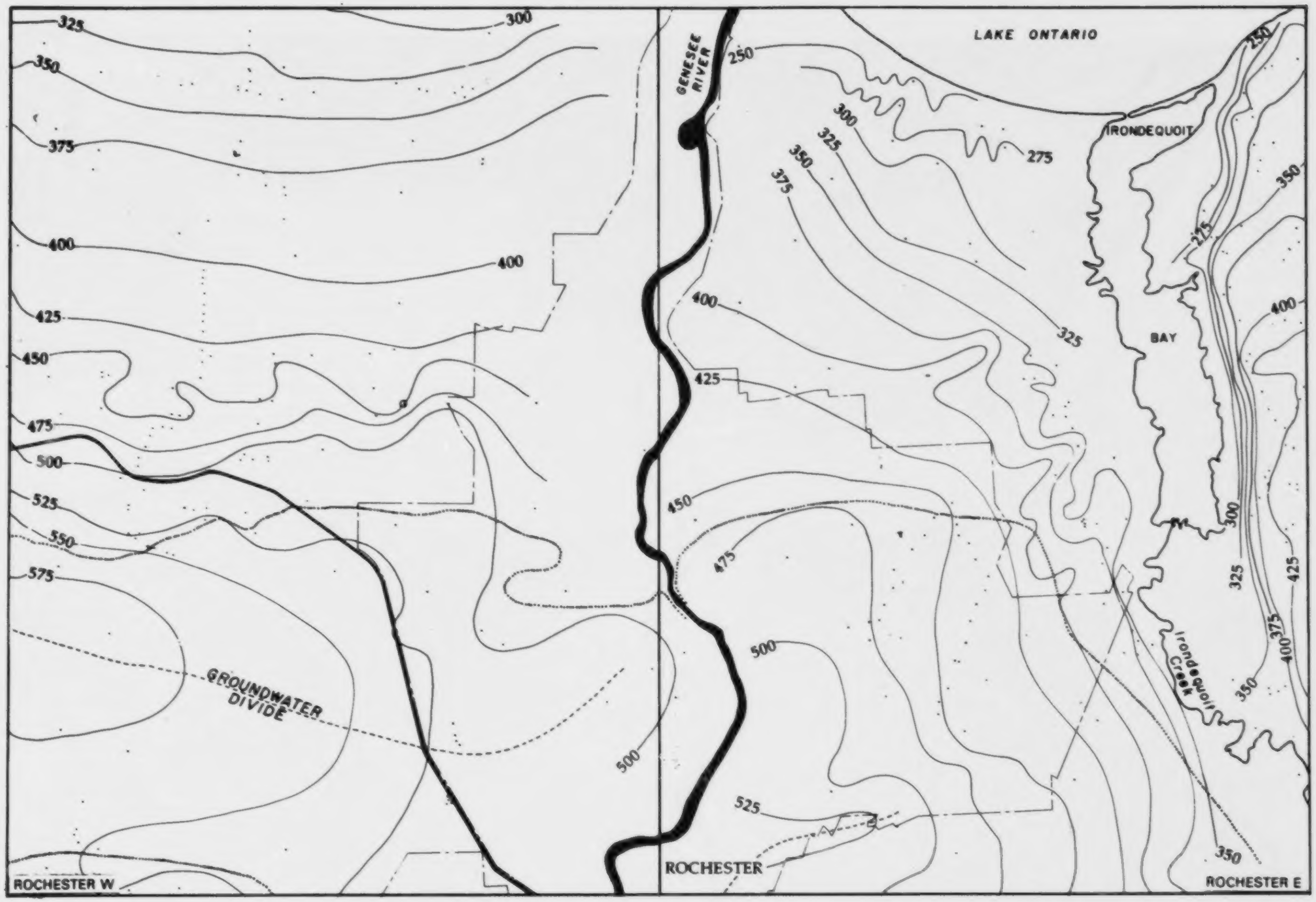

LAKE ONTARIO
GENESEE RIVER
IRONDEQUOIT
BAY
Irondequoit Creek
ROCHESTER W
ROCHESTER
ROCHESTER E
GROUNDWATER DIVIDE
325
350
375
400
425
450
475
500
525
550
575
300
250
275

Figure 4-2. A portion of the Groundwater Contour Map prepared for Monroe County, N.Y. Contour interval 25 feet.

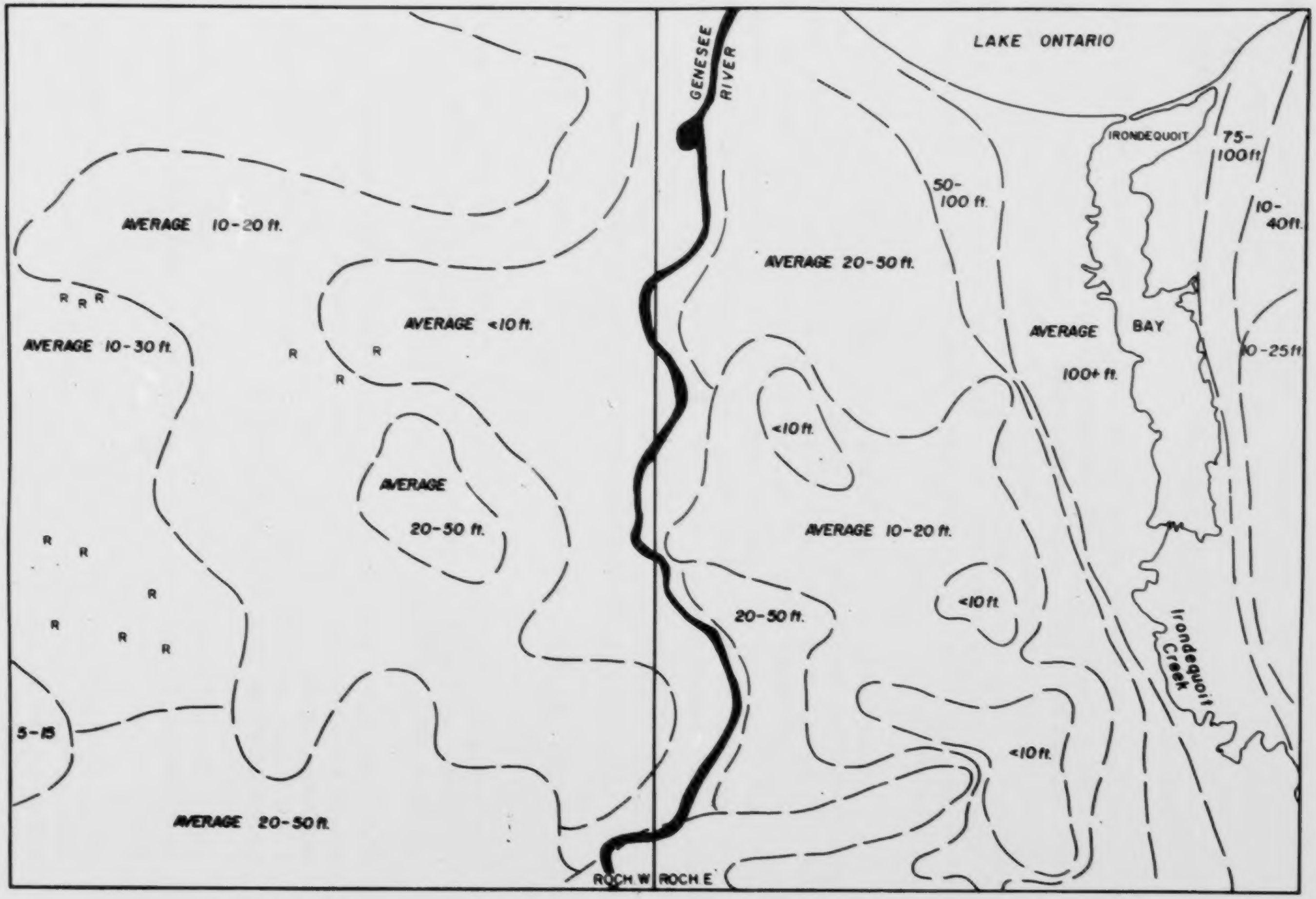

LAKE ONTARIO
GENESEE RIVER
IRONDEQUOIT BAY
Irondequoit Creek
75-100 ft.
10-40 ft.
10-25 ft.
50-100 ft.
AVERAGE 20-50 ft.
AVERAGE 100+ ft.
<10 ft.
AVERAGE 10-20 ft.
<10 ft.
20-50 ft.
<10 ft.
AVERAGE 10-20 ft.
R R R
AVERAGE 10-30 ft.
AVERAGE <10 ft.
R
R
R
AVERAGE 20-50 ft.
R R R R R R
5-15
AVERAGE 20-50 ft.
ROCH W
ROCH E

Figure 4-3. A portion of the Thickness of Overburden Map prepared for Monroe County, N.Y. "R" represents rock outcrops.

include all surface streams, lakes, and major drainage divides (Figure 4-2); and

- a map showing thickness and/or character of the overburden sediments, including any known aquifers, well fields, or highly permeable deposits. This map should be as detailed as available information allows (Figure 4-3).

Maps similar to these were constructed for the Monroe County study, generally using contour intervals of 25 feet (12). The basis for constructing such maps was a 1935 water well survey for the county, supplemented primarily by extensive highway, sewer project, and engineering boring logs. No recent geologic maps for the surficial geology of the entire county existed, although mapping at a 1:250,000 scale was in progress at a nearby university.

It is important in the construction of all such maps that sufficient data be available to make the effort worthwhile and that the finished map product will actually be a useful tool in the hydrogeologic modeling of suspected sites. It should also be realized that such maps would have a variety of uses for local town boards or planning and environmental agencies when the study is complete. It is recommended that the maps be prepared at the scale of 1:24,000 for ease of comparison with the dump site inventory, and that all data points be shown on all maps so that their reliability can easily be ascertained.

These maps serve several important functions during the study:

- the maps provide a convenient format to record and display all the geologic data collected that is needed for hydrogeologic site analysis;
- the actual construction of the maps themselves constitutes the basis of the regional hydrogeologic model and requires the project geologist to formulate a coherent view of the salient factors controlling the hydrogeology;
- the data is all reduced to a common scale and made available to all project personnel and consultants; and
- discrepancies in the data are more easily identified. Suspect or anomalous data can be corroborated or discarded.

SUMMARY

The geologic data base is the key to understanding the hydrogeology of sites. The collection of this information, although time consuming, is much less expensive than collecting similar data through fieldwork with exploratory test borings. This analysis is the basis for the geologic ranking of sites described in Chapter 5.

CHAPTER 5

HYDROGEOLOGIC HAZARD ANALYSIS

INTRODUCTION

A number of comprehensive systems have been proposed to rate the hazard potential of waste disposal sites. The most recent of these by the Mitre Corporation (13) reviews and compares the other major existing models. The other models are known as the LeGrand (14), the Surface Impoundment Assessment (SIA) (15), the EPA Solid and Hazardous Waste Research Division (SHWRD) Predictive Method (16), and the Rating Methodology Model (17).

In general all of these comprehensive systems are intended to rank sites when a considerable amount of information is available on site contents, site operation, and engineering parameters. Some also consider such factors as air pollution and explosion potential.

The methodology described in this report was designed to inventory and rank active and inactive sites for which little or no information is available. Although pertinent data collected during this study is used to develop a site profile or description, the scanty information available does not readily lend itself to the more sophisticated approaches that have been developed to deal with the known, high priority sites currently under investigation by various state and federal agencies across the country.

This study does not attempt to deal with the comparative risks associated with specific chemical substances, but rather with the hydrogeologic conditions that control the migration of fluids under typical geologic circumstances. Direct contamination of groundwater or dwellings near the site is considered the primary concern. This approach dictates that sites with private or public water wells close by should receive the highest priority. Many of the sites have been closed and the land developed so that no direct evidence of activity is necessarily visible at the present time. Once a site has been identified and all available information compiled from historic aerial photographs and records (as previously described in Chapters 2 and 3), a hydrogeologic ranking is assigned based on the best available surface and subsurface information (Chapter 4).

Although the method described here is necessarily less comprehensive than those listed above, an effort has been made to devise a scheme that is compatible with existing ranking models. The similarities apply basically for measurement parameters, such as distances from sites to critical targets (i.e., water wells), or measurement categories, such as soil permeability ranges.

This ranking scheme is an attempt to apply a relative hydrogeologic ranking scale to all dump sites within a specific area, such as a county, so that significant sites can be further investigated in a logical, consistent, scientific, and efficient manner. Sites for which detailed information is available can be evaluated more definitively by such methods as the Mitre Corporation Site Ranking Model (13).

GEOLOGIC VARIABLES TO BE CONSIDERED

It is recommended that the geologic ranking of the sites be completed by a local geologist with experience in the areas of groundwater geology or hydrogeology.

The hydrogeologic ranking process takes into consideration a large number of interdependent variables. Evaluation of these factors is necessary to effectively assess the hazard potential associated with contaminant migration through the groundwater system. The factors evaluated in the Monroe County study were:

1. overburden geology (sedimentological and textural characteristics);
2. estimated overburden permeability;
3. relief or geomorphology (surface processes or history);
4. separation of waste from groundwater;
5. groundwater gradient;
6. bedrock character (including structures, faults, joints); and
7. soil mineralogy and texture.

These factors would be appropriate for most areas of the country but could be modified by the project geologist where necessary to reflect unusual geologic conditions. The factors are applied through the use of the Geologic Ranking Sheet, pp. 60-61.

Overburden Geology

The properties, geometry, and stratigraphy (layering) of the unconsolidated overburden sediments may cause groundwater or fluids to be concentrated in discrete zones or layers and to move at varying speeds in either the horizontal or vertical directions. Consideration should be given to these possible effects when relative permeabilities are being estimated. Overburden deposits are seldom homogeneous, especially in glaciated regions. Examples: (1) relatively impermeable glacial lodgement tills are commonly overlain by more permeable ablation till or outwash gravels; (2) relatively impermeable lake clays or silts may contain sandy layers that allow significant horizontal fluid migration at specific intervals; (3) arid soils may contain relatively impermeable caliche or "hard pan" horizons which are discontinuous or highly jointed.

A three-dimensional groundwater flow model should be envisioned which includes the effects of different layers, textures, or structures (joints, faults) on relative permeabilities. A generalized understanding of the most obvious overburden characteristics can be developed by evaluating a number of existing groundwater well logs or engineering borings throughout the general area of the study. Any property of the sedimentary sequence that substantially enhances vertical or horizontal groundwater flow would tend to increase the potential hazard. Any condition which essentially limits or contains fluids within acceptable vertical or horizontal limits would be expected to decrease the hazard (see Separation of Waste from Groundwater Table, pp. 53-55, and the Geologic Ranking Sheet, p. 60. A general working knowledge of sedimentary depositional mechanisms and normal sediment textures is required to accurately evaluate this factor.

Estimated Overburden Permeability

Permeability (or hydraulic conductivity) is the capacity of a soil or rock formation to transmit fluids. It is dependent upon the pore spaces in sediment and their interconnections. It is measured as the rate at which a fluid moves a given distance in a specified time interval under a specified hydraulic gradient and temperature. The most common units are given as centimeters per second (cm/sec).

Typical permeability ranges for soils and rocks are given in Table 5-1 with approximate equivalents in English units.

TABLE 5-1. TYPICAL SOIL AND ROCK PERMEABILITY RANGES

Soils

		Permeability*	
		Metric Units	English Units
clay, silty clay	lacustrine (lake) sediment, fine-grained tills	$<10^{-6}$ cm/sec	<.03 in/day
silt, sandy silt	lacustrine sediments, flood-plain sediments, medium-grained or jointed tills	10^{-6} to 10^{-3} cm/sec	.03 in to 3 ft/day
fine to medium sand, silty sand	coarse lacustrine dune and river sands	10^{-3} to 10^{-1} cm/sec	3 ft to 300 ft/day
coarse sand, gravel	coarse river sediments, beach sands, glacial outwash	$>10^{-1}$ cm/sec	>300 ft/day

Rock

	Permeability*	
	Metric Units	English Units
Shales, well-cemented fine-grained rocks, massive igneous rock (unjointed)	$<10^{-6}$ cm/sec	<.03 in/day
Siltstones, well-cemented sandstones and conglomerates	10^{-6} to 10^{-4} cm/sec	.03 in to 3 in/day
Weakly cemented sandstone and conglomerates; some fracturing	10^{-4} to 10^{-2} cm/sec	3 in to 30 ft/day
Highly fractured rocks, solution affected carbonates	$>10^{-2}$ cm/sec	>30 ft/day

*Permeability: The rate of water flow through a cross section of one square centimeter under a unit hydraulic gradient.

The lowest velocity categories for soil and rock (<0.03 inches/day) are considered a "decreased hazard" unless they create the so-called "bathtub" effect whereby leachate seeps or springs form at the perimeter of sites when increased infiltration from rainfall exceeds the capacity of the soil to absorb the local precipitation.

Soils or rocks with permeabilities of 3 to 300 feet per day or more would be considered unlikely to contain fluids effectively. Values between these extremes must be evaluated in combination with other characteristics, such as local relief or groundwater gradient, in order to estimate potential leachate movement. The following examples are intended to illustrate the complexities involved.

In predominantly clayey to silty soils natural fractures may be more important than permeability in the evaluation of fluid migration. Fractures are caused by glacial deposition and unloading stresses, tectonic stresses, erosional unloading, and soil shrink-swell cycles related to climatic fluctuations.

When the overburden sediments are stratified and variable in composition, both vertical and horizontal flow conditions should be considered. A thin sandy layer in otherwise impermeable fine-grained sediments may allow significant, although restricted, horizontal transport.

It must be kept in mind that fluid contaminants do not necessarily mix with groundwater. Some fluids may move at or above the surface of the water table (volatiles, gasses, or low density liquids). Other heavy contaminants may sink through the groundwater aquifer and concentrate near the lower confining surface. Such heavy fluids may follow the bedrock slope under the influence of gravity, rather than moving entirely with groundwater flow. Some ionic species can move through the local groundwater at rates greater than the actual groundwater flow velocity. For the above reasons it should not be assumed that all potential problems are downgradient or that contamination is moving at the average groundwater velocity. Any eventual sampling of sites should be designed to take these possible effects into account. However, most substances present should be carried, to a degree, in the direction of the predominant groundwater flow.

Relief or Geomorphology

The relief or geomorphology at or near a site is evaluated from two different but related perspectives. First, the relief at the site will directly affect groundwater gradients or runoff potential as well as general site integrity relative to erosion, mass wasting, slope failure and potential leachate plume asymmetry. Second, natural landforms seen on aerial photographs taken prior or subsequent to site development may permit reasonable conclusions to be drawn concerning the character of the subsurface sediments or structures. This is especially true for glacial, floodplain, dune, beach, karst, volcanic, or active tectonic landforms where some direct inferences concerning anticipated subsurface permeability or fracture zones can be made. Such information is best integrated with a comprehensive view of the most recent geologic events or processes known to have affected an area.

Examples: Relict glacial lake shorelines or glacial meltwater channels are assumed to concentrate well-sorted, permeable sands and gravels, whereas glacial drumlins (oval hills) usually signify impermeable materials. Karst solution terrain or recently active fault zones may signify near-surface conditions that control groundwater migration and allow rapid migration in selected directions not predicted by surface relief.

Relief and geomorphology contribute information that overlaps with the categories of overburden geology and groundwater gradient, but constitute a different (indirect) source of information with which to evaluate leachate migration potential.

A "higher hazard" would be one involving enhanced leachate migration, such as might occur with an "abandoned" glacial outwash channel (glacial meltwater origin) trending from a site toward an area of potentially serious impact. A "lower hazard" would result from physiographic and geologic properties conducive to leachate attenuation or containment, such as a gently undulating glacial till plain with low relief and no adjacent stream.

Separation of Waste from Groundwater Table

The separation of waste from the surface of a saturated zone (either a perched or a permanent water table) is of critical importance. Obviously, situations where groundwater is at or above the base of the waste are potentially the worst. However, waste sites in permeable gravels above a deeper water table may be equally bad. Separation of waste from groundwater must be evaluated in conjunction with the overburden character and estimated permeability. Arbitrary distance criteria alone are not always adequate for a useful ranking of sites.

In this report "highly permeable" includes permeabilities $>10^{-3}$ cm/sec; "moderately permeable" includes the range from 10^{-3} cm/sec to 10^{-5} cm/sec; "relatively impermeable" sediments have permeabilities $<10^{-5}$ cm/sec (Table 5-1).

A "higher hazard" exists when groundwater is in contact with or separated from waste only by highly permeable sediments ($>10^{-3}$ cm/sec) or rock (jointed or weathered). Infiltrating precipitation or migrating groundwater are presumed to be in contact with or carry pollutants readily into surrounding aquifers. The distance of separation could be less than 20 feet in moderately permeable materials but may be greater in sand or gravels. Narrow, discrete zones of high permeability, such as faults or permeable, dipping rock layers, could also place sites in this category.

An "intermediate hazard" exists when waste is separated from local groundwater by 20 feet or more (in humid climate) of moderately permeable sediment (10^{-3} to 10^{-5} cm/sec) without significant layers or structures that might increase permeability in a restricted zone or layer.

A "lower hazard" exists when waste is separated from groundwater table by 10 to 20 feet of relatively impermeable overburden such as clay-rich glacial till ($<10^{-5}$ cm/sec), or 20 to 50 feet of moderately impermeable overburden with significant amounts of silt or clay.

Obviously these simple criteria cannot cover all potential geologic conditions. The "separation from groundwater" criterion must be evaluated by comparison with or consideration of the local relief and estimated permeability. If two different sites with identical wastes were 20 and 50 feet, respectively, above the water table in highly permeable materials, the difference would be minimal for their relative ranking. Conversely, sites in relatively impermeable clays could be isolated from the water table but may develop the so-called "bathtub" effect where saturation produces marginal seeps and springs.

Clearly, distance criteria are interrelated with overburden characteristics and climate. A knowledgeable integration of all pertinent factors for each climatic zone and type of surficial geology is recommended.

Sites in direct contact with surface streams or ponds are considered equivalent to sites where groundwater is in contact with the waste. In the case of surface water, it is assumed that significant quantities of fluids are likely to follow groundwater flow lines that contribute to sustained streamflow and the water balance of lakes. A simple separation of ground and surface water is unrealistic, although direct surface runoff obviously constitutes an increased hazard. Direct surface runoff of contaminants during storms or at stream bank exposures can be complicated by the greater dilution potential that exists in rivers, as contrasted with the zone of groundwater saturation. However, streams directly adjacent to sites provide direct access for sampling of groundwater entering the stream. Sampling should normally be done during periods of low streamflow when groundwater discharge constitutes a greater proportion of the streamflow.

Sites directly adjacent to water bodies present unusual problems of analysis due to the complex flow of leachate to the stream and the possibility that the stream or lake may be providing recharge to the waste site, especially during periods of variable flow or changing water levels.

Groundwater Gradient (Slope)

The groundwater gradient is the vertical change in elevation of the groundwater surface per unit of horizontal distance. Under similar conditions a steeper gradient implies a faster rate of flow. In humid climates the groundwater surface configuration tends to parallel the topography, but with a more subdued profile. When evaluating the groundwater gradient for two sites an attempt must be made to distinguish between actual groundwater gradients and those artificially steepened by the existing topographic slope. In addition, a steeper gradient is required to produce the same groundwater velocity in finer-grained sediments as compared to course-grained sediments. Thus gradient cannot be used in a straight-forward way to compare sites without taking topography and permeability into account.

Gradients may also vary seasonally in concert with rising and falling water tables in humid regions.

Topographic slope can be assumed to outweigh the effect of gradient in areas of moderate to high relief. Gradient should only be considered independently where moderately to highly permeable sediments are present in areas of little or no relief (topographic slopes on the order of 150 feet per mile or less). Absolute gradient values cannot be assigned to hazard categories on the ranking sheet in most instances.

Groundwater gradients of approximately 10 feet per mile have produced leachate plume velocities of 1 to 4 feet per day in course sands and gravel on Long Island, N.Y. (18). Thus in permeable sediments, even low gradients should be considered indicative of an increased hazard.

At a given site, in uniform geologic materials, the steepest gradient should indicate the direction of greatest potential leachate migration. In any event, the most important use of gradient may simply be as an indicator of the most probable direction in which to evaluate the impact of the site, or where to concentrate additional sampling. Its most useful application is in the evaluation of potential water well contamination near sites.

It is worth repeating the observation made under Estimated Overburden Permeability that contaminants may move not only with the groundwater flow but along the surface of the water table, near the base of the aquifer (controlled by gravity), or through the groundwater at an increased velocity. The occurrence of these phenomena depends on the relative densities, mixing, and immiscibility of fluids.

Bedrock Character

Most disposal sites have undoubtedly been located in unconsolidated overburden or soils. Some sites involve surface disposal or disposal in abandoned rock quarries. If bedrock with moderate to high permeability or unusual structures (e.g., faults) is close to the waste or separated from it by moderate to highly permeable sediments, the influence of the rock should be considered. Because bedrock formations tend to be regionally more homogeneous than overburden sediments, the pathway to potential targets may be easier to predict where pollution has access to rock formations. Fluids in rocks tend to move either through relatively permeable aquifers or along zones of enhanced permeability, such as near-surface joints. Limestone solution terrane (karst) may be the most difficult in which to anticipate pathways. Joints with preferred orientations, fault zones, dipping permeable bedrock layers and cavernous solution zones all provide rapid and highly directional pathways for concentrated contamination.

The general impact of the bedrock should also be considered under Estimated Overburden Permeability. The Bedrock Character section of the Geologic Ranking Sheet is intended to draw attention to any other structural features, joints, or unusual bedding that might directly influence pollution migration either by creating a barrier (diverting flow) or by creating more direct pathways for groundwater and water well contamination.

In Monroe County the only significant bedrock aquifer is a dolomitic shale formation (Lockport Dolomite) containing limited and generally disconnected solution zones or cavities. However, in near-surface exposures the rock is weathered and much more permeable. Joints in shales, dolomites, and sandstones were found to allow significant water movement only in the upper 50 to 75 feet of the rock. At least one large site was aligned with a fault zone which passed through an area where residential water wells had once been actively used. The existence of the fault zone raised the geologic ranking for the site and influenced both the groundwater and water well evaluations. Tunnel construction intersecting faults in the area has demonstrated that faults are a primary locus of groundwater movement at depths to 100 feet or more below the surface.

The evaluation of unusual bedrock characteristics requires a working knowledge of the local rock formations and not just a search of general literature sources if the influence of bedrock is to be realistically evaluated for factors other than general permeability.

Soil Mineralogy and Texture

This category, like that of bedrock character, is designed to allow for the evaluation of conditions other than normal sediment characteristics and permeability. Some soils, or their mineral constituents, have widely-known characteristics that either enhance or decrease their suitability for engineering uses. An example of this is clays that swell or shrink abnormally with seasonal variations in rainfall. Such soils can develop extensive vertical cracking during the dry season, which enhances rainfall infiltration and groundwater recharge when wetter conditions return. Another example is clay minerals which have strong cation exchange capacities. Other fine-grained soils tend to become highly unstable on low slopes when saturated. Tropical laterite soils and arid caliche horizons may be strongly indurated and relatively impermeable near the surface. Unusual factors such as these are usually characteristic of broad areas or the rock types from which the soils have evolved. Such conditions are generally known by persons familiar with the local geology and might be found in specific local engineering project reports or on soil maps.

If no specific conditions are known that significantly increase or decrease local hazards, sites may all be ranked as intermediate or this factor might be disregarded in the ranking scheme (with appropriate point value adjustments).

GEOLOGIC RANKING: WATER WELL EVALUATION

One of the important aspects of ranking active and inactive waste sites involves consideration of the pathways by which pollutants can migrate from a site and thereby produce a significant environmental hazard. For many sites, obvious surface contamination is not apparent. In most cases the movement of groundwater through the soils or rock formations on or near a site is presumed to be the mechanism by which contaminants are dispersed or transported throughout the surrounding subsurface environment.

Because individuals or communities may utilize groundwater directly as a source of drinking water, the location of public, private, or individual water supplies or well fields near sites is accorded the highest priority in the geologic ranking system. Proposed distance limits within which sites are given priority for potential well water contamination have been suggested by the Mitre Corporation (13) and others. Individual wells within 2000 feet downgradient of a site and public and private water supplies within a 3 mile radius downgradient are considered to be in the greatest jeopardy. However, because the geologic information may be incomplete and groundwater flow is often unpredictable, all relations between sites and wells within these distances should be conservatively evaluated.

A simple hydrogeologic model, based on assumptions or scanty information, only provides information on the most logical place to perform initial tests of water samples (downgradient), but all wells nearby may eventually have to be analyzed. This results from the fact that groundwater movement in heterogeneous overburden sediments is unpredictable, especially where the volume of water pumped from shallow aquifers is large or where the aquifers are highly irregular in shape. Continuous pumping of several shallow aquifers penetrated by one or more wells can substantially alter the groundwater flow paths over a wide area adjacent to the pumping wells.

Because not all pollutants move with or mix readily with groundwater (see previous groundwater discussion) complex patterns of pollution dispersion are possible. For the Monroe County study, distance criteria of 0 to 1000 feet for individual wells and 0 to one-half mile for public and private water supplies were initially used. The choice of distance criteria should be dependent upon some basic knowledge of geologic conditions influencing groundwater movement and use in each region.

If an identified site is found to have wells within the limits specified above, the site is placed in the category recommended for testing of existing wells. Where two or more wells are located within the distance limits above, the pertinent groundwater information (especially gradient) is used to establish a priority list of wells recommended for testing (Table 3-1). However, if hydrogeologic indications suggest that groundwater conditions are variable or unpredictable, testing of all nearby wells within the prescribed distances is advised, especially within the 1000 foot perimeter. For large sites or permeable aquifers the minimal distance criteria should probably be increased to 2000 feet for individual wells and 3 miles for public or private water supplies.

APPLICATION OF GEOLOGIC RANKING SYSTEM

A numerical "ranking" scheme is basically an information gathering and documentation device. It should:

. be simple to apply;

- not be complicated by too many parameters, rating intervals, or arbitrarily designated multiplier factors;
- have intervals that are discrete, separate units and do not overlap;
- include an indication of the degree of uncertainty of the variables involved; and
- not be used to the exclusion of common sense or strong circumstantial evidence analyzed by experienced personnel.

The geologic ranking system incorporated in this study is designed to divide sites into high (.01), intermediate (.02), or low (.03) priority based on the anticipated geologic conditions governing leachate (groundwater) occurrence, production, migration, or accumulation. Ranking is based on the score the site receives on the Geologic Ranking Sheet (Figure 5-1).

The ranking system has as its prime consideration the potential or inferred effects that groundwater contamination would have on people or water resources on or near the sites. The highest priority sites are those where leachate could impact water supplies. Therefore it is important to evaluate sites with nearby drinking water supplies first.

After the water supply evaluation has been completed, all sites are ranked geologically. The "highest priority" sites (.01) are those where leachate might pond near the surface, move at shallow depths off the site, or resurface in concentrated amounts a short distance away.

Sites at which the soils (overburden sediments) are relatively impermeable and where the groundwater considerations are judged to create a less severe impact are ranked as "intermediate priority" (.02).

"Lower priority" sites (.03) would be those located on steep hill slopes and presumed to be better drained and less likely to have accumulated undetected leachate in significant quantities, or sites in which most of the factors on the site ranking sheet indicate that either attenuation or containment are excellent. However, such low priority sites may be individually re-evaluated if other data are available on contents or unusual localized impacts. Sites adjacent to larger water bodies such as lakes, bays, or major rivers were also placed in the lowest geologic category in the Monroe County study because leachate entering such water bodies does not usually accumulate in concentrated amounts but is flushed away and diluted or taken up

GEOLOGIC RANKING SHEET
FOR GENERAL COMPARISON OF ABANDONED LANDFILL/DUMP SITES

SYMBOLS USED IN COLUMNS
X PROBABLE EFFECT
U UNCERTAIN: LIKELY EFFECT
⊗ EFFECT OF OVERRIDING SIGNIFICANCE
Superscripts refer to footnotes.

FACTORS TO BE EVALUATED	PRESUMED EFFECT[1]		
	A	B	C
	HIGHER HAZARD	INTERMEDIATE (UNCERTAIN)	LOWER HAZARD
OVERBURDEN GEOLOGY[2]			
ESTIMATED PERMEABILITY[3]			
RELIEF, GEOMORPHOLOGY[4]			
SEPARATION OF WASTE FROM GROUNDWATER[5]			
GROUNDWATER GRADIENT[6]			
BEDROCK CHARACTER[7]			
SOIL MINERALOGY; TEXTURES[8]			
NUMBER OF ENTRIES			
MULTIPLIER	3	2	1
ENTRIES X MULITPLIER			

SUBTOTAL ____
ADDITIONAL FACTORS ____
TOTAL POINTS: SITE RANK ____

SITE NAME/NO.____________

SITE RANK
(CHECK ONE)

.01 HIGHEST PRIORITY (17-21 PTS)	☐
.02 INTERMEDIATE PRIORITY (12-16 PTS)	☐
.03 LOWEST PRIORITY (7-11 PTS)	☐

___ TENTATIVE ___ FINAL

NOTE: IN CASES WHERE MORE THAN HALF THE CRITICAL FACTORS MUST BE RATED AS UNCERTAIN (U), THE RANK SHOULD BE TENTATIVE.

ADDITIONAL FACTORS
(CIRCLE AND ADD TO CHART)

THESE POINTS MAY INCREASE (+1),
DECREASE (−1),
OR NOT AFFECT (0) SCORE

VERY LARGE SITES (20+ ACRES)	+1
ENGINEERING/GEOLOGIC DATA ON OR NEAR SITE	0, −1, +1
GEOLOGY EXTRAPOLATED CONFIDENTLY FROM NEARBY	0, −1, +1

DESCRIBE IMPORTANT OR OVERRIDING FACTORS BELOW IF APPROPRIATE (DESCRIBE SPECIAL CONDITIONS): ______
____
____
____
____
____
____
____

Figure 5-1. Geologic ranking sheet.

Footnotes to Accompany Figure 5-1.

1. PRESUMED EFFECT: A decision is required as to whether each inferred or documented FACTOR would increase or decrease the hazard relative to leachate production, migration, or attenuation. No simple, uniform guidelines can be set forth that cover all situations or geohydrologic complexities.

2. OVERBURDEN GEOLOGY: Based on inferred nature of unconsolidated sediments, would leachate occurrence be likely to increase or decrease human exposure hazard?

3. ESTIMATED PERMEABILITY: Is estimated permeability of unconsolidated materials likely to increase or decrease exposure risks? Include the estimated effect of either aquifers or aquicludes or inferred combinations.

4. RELIEF, GEOMORPHOLOGY: Does relief on or adjacent to the site influence the occurrence or migration of leachate so as to increase or decrease the exposure hazard?

5. SEPARATION OF WASTE FROM GROUNDWATER: Does the estimated depth to the water table imply a high or low risk for contamination or leachate production? Relate to permeability and gradient factors.

6. GROUNDWATER GRADIENT: Gradient is dependent on local relief, estimated permeability, aquifer characteristics and rainfall patterns. Steep or flat gradients by themselves cannot be presumed to have similar effects in each case. Judgment is required on local conditions.

7. BEDROCK CHARACTER: Is local bedrock an important factor in the local hydrologic system? If so, do textures or structures in the bedrock produce asymmetry or enhanced flow of a potential leachate plume (flow along bedding, joints, faults, or solution channels, etc.).

8. SOIL MINERALOGY; TEXTURES: Are there known textural or mineralogical factors that could enhance or diminish leachate migration, such as strong cation exchange or swelling/shrinking clays (cracking)? Are seasonal effects such as rainfall duration, infiltration capacity, freeze-thaw conditions, vegetation cover, etc., of significance?

by various natural biologic systems. If large water bodies are heavily used for recreation or drinking water, any potential problem sites should be referred to existing health or conservation departments who have the authority and existing monitoring facilities to deal with such public health concerns. These are considered special cases that do not share the problems of sample accessibility common to inactive sites where excavations or wells would be required to ascertain the nature of hazardous substances.

Geologic Ranking Sheet

The Geologic Ranking Sheet (Figure 5-1) is intended to provide a prioritized list of sites based on potential hazard and hydrogeologic and other data by:

- providing a means of organizing the process of geologic comparison of sites;
- preventing inconsistencies and reduce oversights that might occur when dealing with large amounts of data;
- providing a permanent record for other project personnel and allow for discussion or independent review of site characteristics; and
- allowing for updating of information during the course of the continuing data collection effort and evaluation process.

The main purpose of the geologic ranking process is to provide a uniform and systematic comparison of sites within the limits of the available data. For each site a judgment is made as to whether each "factor" on the ranking sheet increases or decreases the potential for substances to accumulate on or migrate away from the site. All available engineering or geologic information and potential interrelations among factors are considered before filling in the appropriate symbol (x,u,⊗) in each column. When this information is completed, the number of entries in each column is multiplied by the rating value (1, 2, or 3). The scores for the three columns are added to compute the subtotal.

An adjustment called "Additional Factors" has been incorporated in the ranking sheet to allow for further subjective modification of the subtotal after all sites have been evaluated. This is intended to allow for discrimination between sites which have identical subtotals that were based on different types of information. For example, two sites in similar geologic settings may produce identical geologic ranking scores (subtotals), but one site score may have been derived from good engineering boring information, whereas the other may have been based only on extrapolation of the surface geology or known geologic history of the general area. The site with the best documented data may be assigned additional points (+1 or-1) depending upon whether the supporting information is considered to increase or decrease the hazard. For geologically equivalent sites, the larger site might receive an additional point in this same category.

It is important to document the reasons for these subjective adjustments in the space provided at the bottom of the form. After the numerical score has been computed, the site is assigned to one of three geologic categories (highest, intermediate, or lowest priority). For borderline cases with point values from 16 to 17 or 11 to 12, the data may be reexamined and reevaluated for factors of overriding importance. This would include any verifiable geologic condition considered as having a predictable and significant effect on hazard potential, whether positive or negative. These conditions can also be noted in the appropriate space provided and a tentative or final rank assignment made (.01, .02, or .03). For sites in which more than half of the "factors" are marked as "uncertain" (u) a tentative rank should be assigned pending acquisition of further data or supporting information. Borderline sites should be carefully reviewed to ascertain that an arbitrary numerical score has not overrated or underrated a site.

SUMMARY AND CONCLUSIONS

This ranking system is different from those already devised for more detailed analyses or comparisons of known sites, such as the systems by LeGrand (14), Kufs et al. (17), or the Mitre Corporation (13). These detailed ranking systems cannot be applied to the type of information developed from this more general survey of sites. However, such sophisticated systems might be appropriately used in refining site rankings after a more definitive investigation of the highest priority sites has begun, or where a few sites have been well documented.

Although subjective and tentative, the Geologic Ranking Sheet permits a consistent ranking of sites with an indication of the degree of uncertainty involved, and it allows for modification of the geologic ranking of any site should additional information become available.

A conscientious effort must be made to apply the criteria carefully so that the relative ranking of sites is internally consistent for each geographic region. Relative ranking scores of two different sites in widely separate geologic regions may not be strictly comparable.

Even within a single region, a strictly numerical comparison of such site rankings should be avoided and geologic expertise or experience substituted where appropriate. The system requires knowledgeable decisions to be made for each of the "Presumed Effects"; the ranking sheets should not be routinely filled in by persons with insufficient geologic or hydrologic background. Complex interactions among the "presumed effects" resulting from unique geologic conditions may occur. A geologist analyzing the sites should be capable of anticipating the more obvious of these complications and should make allowances for such situations in the ranking process.

The present scheme is mainly a method by which an orderly analysis may proceed and be documented for updating or reevaluation. An important aspect of the entire survey process is the recording of a great deal of information. This permits the study team to evaluate sites so that a more efficient allocation of limited resources can occur. It also documents activities and findings so that the study can continue in an uninterrupted manner if project staff change.

Points of Emphasis

1. The surficial geology of the numerous regions (geologic provinces) within the United States, as it pertains to the occurrence and movement of groundwater, should be evaluated by a hydrogeologist familiar with the local geologic conditions.

2. The geologic evaluation of potential groundwater contamination (hazard potential) used in the Monroe County, N.Y., study may have to be modified for other geologic provinces (especially nonglaciated regions). However, the basic data collection process and integrated analysis of the hydrogeology should be applicable using a very similar geologic ranking sheet (with possible minor modifications devised to suit the local geology).

3. The Geologic Ranking Sheet is designed to allow a subjective but practical comparison of high, intermediate, and low hazard site hydrogeology. It also serves to document the information and the process by which the ranking is accomplished. As such, it becomes a valuable part of the data base to be used for reference and possible revision or updating.

CHAPTER 6

APPLICATION OF METHODOLOGY TO RANK SITES

INTRODUCTION

Previous chapters in this report describe methods for locating inactive waste disposal sites and suggest a ranking system for the separate categories of site activity, land use, geology, and proximity to water supplies. This chapter describes how the rankings are combined in a matrix to establish priority sites for further investigation. The application of the methodology is illustrated for one town in Monroe County. The final report for the town is also described.

CATEGORICAL RANKINGS: A REVIEW

Site Activity

The initial categorization of sites occurs when the photointerpreter identifies a potential area for inclusion in the inventory. Chapter One suggests five classifications that could be applied, depending on how clearly the activity can be characterized from information contained on the aerial photographs (Table 2-2).

- identifiable dump/landfill
- possible dump/landfill
- unspecified fill
- lagoon, surface impoundment, or bermed pit
- auto junkyard, waste piles, or salvage area

The assignment of these classifications to specific sites is subsequently refined based on supplementary information obtained from agency records, interviews, and field checking, as described in Chapter Three. After the verification stage, the number of confirmed waste disposal sites will increase, assuming the photointerpreter has been careful initially to classify as dumps/landfills only those sites for which prior knowledge or clear aerial photographic evidence of waste disposal activity exists. This increase occurs as sites initially categorized in the possible dump/landfill and unspecified fill categories are found to have received waste.

Land Use

During the initial investigation all sites are ranked for land use activity at the time of photointerpretation (Table 2-3). The information is taken from the most recent year of aerial photography. This classification is later verified or corrected by field checks.

Geology

Using relevant geologic criteria, the hydrogeologist ranks sites according to potential hazard (Chapter 5). This is done only for confirmed dumps/landfills.

Proximity to Water Supplies

Confirmed dump/landfill sites are ranked for proximity to drinking water supplies. Public and private water supplies within one-half mile and individual wells within 1000 feet are each ranked for contamination potential (Table 3-1). All potentially impacted drinking water supplies and associated sites are referred immediately to the appropriate county or state agency for action (Chapter 3). These sites should also be placed in the evaluation matrix described below since follow-up action based on site proximity to a nearby water supply may be limited to a recommendation to cease using the water for drinking purposes. It is also important to provide a basis at this stage for future site-specific evaluations of potential soil, sediment, and air quality impacts.

SITE RANKING TO ESTABLISH PRIORITY SITES FOR FURTHER INVESTIGATION

Once values have been assigned in all of the separate ranking categories, a matrix is constructed to establish final site rankings. In accordance with the response phase described later in this chapter, matrices are constructed separately for each municipality. In Monroe County, only confirmed dumps/landfills, junkyards, and lagoons were included in the matrices since information on the remaining sites was too limited to justify further investigation. However, records on sites in the possible dump/landfill and unspecified fill categories were maintained in the event that more information became available at a later date.

Because little is known at this stage about the composition of the waste contained in most sites, the assumption is made that any confirmed disposal site may contain hazardous waste. It is the potential impact of assumed hazardous wastes, then, which is evaluated by using the matrix. The matrix itself combines the variables considered most important for the evaluation of potential impact in the particular area under study. In Monroe County, the selected primary variables were land use and geology (Figure 6-1).

DUMPS

LAND USE

		.01	.02	.03	.04	.05	.06
	.01						
GEOLOGY	.02						
	.03						

Figure 6-1. Matrix for ranking waste disposal sites

As can be seen from the above matrix, site rankings range from the extreme values of .01 Geology, .01 Land Use (higher geologic hazard and continuous site occupancy within 100 feet) to .03 Geology, .06 Land Use (lower geologic hazard and part-time occupancy no closer than 1000 feet). The actual priority ordering of sites within these extremes is dependent on the relative importance of the primary variables.

Once all sites within a municipality are assigned a priority ranking, the response phase of the study is initiated.

RESPONSE

The response phase consists of three basic components:

1. publication of the municipal report;
2. referral to appropriate agencies for follow-up, site-specific action; and
3. notification of water supply owners, well owners and site landowners.

Municipal Report

A report consisting of information distilled from the SAR and the municipal map is prepared and distributed to local and state officials. The information is presented using the Site

Information Form (Appendix G) accompanied by a 1"=800' scale site map designed to show the general location and shape of the site. The SAR forms are not publically released since these are considered working documents used to record preliminary information.

Referral

The municipal reports are referred to the appropriate agencies for action. Copies of the SAR forms and site orthophotomaps should be made available to these agencies to facilitate the follow-up investigations.

Notification of Water Supply Owners, Well Owners and Site Landowners

Prior to the distribution of the municipal report, letters are sent to the individual homeowners with wells or public or private water supply system owners potentially impacted by confirmed waste disposal sites and to the current owners of all dump/landfill sites. Sample letters sent to these individuals by the county Health Department can be found in Appendices H and I. It is also helpful to attach a copy of the Site Information Form and site map to the letters sent to the landowners.

APPLICATION OF METHODOLOGY: TOWN OF GREECE

The Town of Greece, N.Y., with a population of 82,000, is an urban ring town located northwest of the City of Rochester. With an area of 42 square miles, it is the largest of the 19 towns in Monroe County. Greece is a town in transition, with suburban development expanding from the eastern and southern portions into the more rural northwest sections. There is little industry except for the Eastman Kodak Company, which is located in the more developed southeastern section.

The town employs a full-time planning staff, as well as a building inspector, town engineer, and public works personnel. The Greece Conservation Advisory Board, appointed by the town board to advise on environmental matters affecting the town, is knowledgeable and active in pursuing environmental problems. Thus, the town possesses many resources that were valuable in clarifying and verifying the information gathered as part of the County's inventory of active and inactive waste disposal sites.

Greece is served by a public water supply system and has a water billing department with computerized records for water service provided by the town. Individual water wells are still used by some homeowners but there are no central records locating these wells.

Identification of Sites

When Monroe County first began to inventory the location of dump/landfill sites in the fall of 1978, sites were identified through a public call-in campaign, a record search, and interviews with local officials. This resulted in the identification of 10 sites in the Town of Greece. Of these 10, 2 were subsequently eliminated after aerial photointerpretation was conducted using photos from 1951, 1961, 1970, and 1975-8. One site was removed because it was active prior to 1950. (The LRC had decided to limit the investigation to sites that were used after World War II.) The second site was never located on the aerial photographs.

After the 4 years of aerial photography were systematically reviewed and interpreted, an additional 33 potential sites were identified. These 41 sites were initially classified by the photointerpreter as follows:

11 - Identifiable Dumps/Landfills includes
seven of the original sites)
19 - Possible Dumps/Landfills
11 - Unspecified Fills (includes one of the
original sites)

---

41 - Total

Site Characterization

At this stage town officials were contacted to clarify which possible dumps/landfills and unspecified fills were actually used for waste disposal. During the interviews additional information was also obtained on the known dumps/landfills. The orthophotomap of each site with the maximum boundary delineated over current land use was shown to the assistant town supervisor, a town planner, and town conservation board members. Comments on each site were recorded on the SAR forms. Sites were also field checked, which produced changes in site classifications as shown in Table 6-1.

Table 6-1. Categorization of Sites, Greece, N.Y.

	Dumps/ Landfills	Possible Dumps/ Landfills	Unspecified Fills	Total
After Photo-interpretation	11	19	11	41
After Interviews with Local Officials	19	13	6	38*
After Field Inspection	21	11	6	38

* 3 sites were eliminated because they were found to be clean fill for construction or landscaping

Several benefits of the methodology can be shown from these findings:

1. by using aerial photography, 41 sites were identified. Of these, 21 were actually confirmed to have received some form of waste disposal from information obtained through interviews, agency records, and field checking;

2. these 21 sites represent twice the number of sites initially identified through the call-in campaign, interviews with local officials, and a records search; and

3. the existence and exact locations of the 21 sites were clearly documented. The photointerpreter was able to eliminate one original site that could not be found on the photos, and to accurately locate other sites that had been incorrectly placed during earlier phases of the study.

Categorical Rankings

Site Activity

As specified previously, only confirmed dumps/landfills, lagoons, and junkyards were included in the site ranking procedure in Monroe County. Since no lagoons or junkyards were identified, only 21 confirmed dumps/landfills were evaluated further.

Land Use

Of the 21 sites, 10 were classified .01 (continuous occupancy on or within 100 feet of the site), 10 were classified .02 (part-time occupancy on or within 100 feet of the site), and 1 was classified .03 (continuous occupancy from 100 to 1000 feet of the site). There were no sites classified .04, .05, or .06.

Geology

Of the 21 sites, 4 were classified .01 (higher hazard), 8 were classified .02 (intermediate hazard), and 9 were classified .03 (lower hazard).

Proximity to Water Supplies

The county Health Department provided a list of the private water supply systems (wells) located in the town. Subsequent research indicated that none of these were within one-half mile of any of the 21 sites. Individual water wells were more difficult to locate. Nevertheless, following the procedures outlined in Chapter 2, 55 potential wells were initially identified within 1000 feet of the 21 sites. Additional record checks reduced this number to one water well which was confirmed to be in use.

Site Ranking to Establish Priorities for Further Investigation

In Monroe County the categorical variables considered most influential in determining potential impact were geology and land use. The resulting matrix for the town of Greece is depicted in Figure 6-2.

DUMPS

		LAND USE		
		.01	.02	.03
GEOLOGY	.01	4	0	0
	.02	3	5	0
	.03	3	5	1

Figure 6-2. Distribution of Waste Disposal Sites for Town of Greece, Monroe County, N.Y.

Since no determination was made by the county LRC of the relative importance of the geology and land use variables, no priority ordering of sites within the individual matrix cagegories was specified.

Response

When the site ranking procedure was completed, a report on the 21 sites was prepared and distributed to the Town of Greece, the Monroe County Legislature, and the NYS Departments of Health and Environmental Conservation (19). The director of the county Health Department notified the owner of the individual water well of the potential hazard and recommended connection to the existing public water supply system. Current site owners were notified that their land had received waste in the past and were encouraged to contact the Health Department if they had additional information on the type of activity and waste disposed. The 21 sites were referred to the state departments of Health and Environmental Conservation for follow-up investigation and evaluation.

One site known to contain potentially hazardous wastes had been previously investigated by the county Landfill Review Committee. The investigation is described in Appendix J.

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APPENDIX A

ADMINISTRATIVE PROCEDURES AND PERT DEMONSTRATION MODEL

ORGANIZATION OF THE STUDY

Participants

In organizing an inventory of waste disposal sites, it is important to decide which agencies, groups, and individuals should be involved and how they should participate. This decision will be based upon the responsibility each has for waste disposal, the expertise they can provide, both personally and through additional resources, and the interest they have in the subject.

The study direction will be strengthened if overseen by a multi-disciplinary committee comprised of county and state agency representatives. This provides access to a wide range of information sources and allows the project findings to be evaluated from a broad perspective. To form a coordinating committee, one should begin by identifying state and local government agencies that have a role to play in solid waste disposal. In Monroe County, key agencies with responsibility for controlling and/or monitoring solid waste include the Monroe County Department of Health and the New York State Department of Environmental Conservation (DEC). In addition, the New York State Health Department conducts tests to determine health impacts of waste disposal sites.

Other agencies that have a nonregulatory role to play should also be identified. In Monroe County, the Environmental Management Council (EMC) provides advice on environmental matters to the county legislature and administration and has a long history of involvement with the solid waste issue. The County Planning Department and the Community Development Office of the City of Rochester are important agencies because of the land use concerns that a study of this nature raises. The industrial sector was also considered important. Appointing an industrial representative to the coordinating committee facilitates the exchange of information between industry and the committee and increases confidence in the results. A representative from the Monroe County Industrial Management Council was considered a logical choice.

Representatives of these various agencies were contacted by the Director of the Monroe County Health Department and asked to participate on the Monroe County Landfill Review Committee (LRC). All accepted the invitation. The Director of Health chaired the committee.

Study Staff and Consultants

In organizing the study, one agency should be chosen to direct the daily work effort and to hire the study staff. In Monroe County the EMC performed this task. Funds for staff and consultant contracts were awarded to the Council. The EMC Director served as Project Director (approximately 1/3 time was allocated to this project), and a full-time research assistant was hired to collect information, research files, interpret photographs and prepare maps, and interview public and private officials. Several summer student interns assisted with various aspects of the work. If funds had been available, an additional research assistant would have been hired, so that one could collect existing data and assist with the air photo interpretation and map preparation (Chapter 2) while the second verified the site activity and prepared the final reports (Chapters 3 and 6).

Two consulting contracts are recommended, one with an air photointerpreter and the second with a geologic consultant.

It is important that any consultants hired for the project be familiar with the local area. The consultants do not need to be employed full-time. In fact, since it takes time to collect existing geologic data from a variety of agencies and private companies, it is better that the individual or firm hired to perform the geologic portion of the study work part-time over a number of months.

Job Specifications

Project Director: an ability to handle all administrative requirements, including the organization of a comprehensive study involving several levels of government, supervision of study staff, coordination with multiple agencies, preparation of consulting contracts, and the preparation of reports.

Research Assistant(s): background in geology or geography; an ability to interpret aerial photographs in stereo pairs; organizational skills; research abilities; map and report preparation; and communication skills.

Air Photointerpreter Consultant: trained or experienced in land use/environmental analysis with background or familiarity with geology, engineering construction methods, quarry operations, highway construction, and landfill operations.

Geologic Consultant: hydrogeologist or geologist with background and experience in hydrology and applied engineering practices.

STUDY PLANNING AND IMPLEMENTATION

The purpose of this section is to provide assistance to those planning and implementing studies based on the methods described in this report. The specific objectives of this section are:

1. to summarize the component activities associated with the method; and
2. to provide the basis for the efficient scheduling and duration estimation of studies based on the method.

To achieve these objectives, a demonstration model based on the Program Evaluation Review Technique (PERT) is presented and described. The model follows the techniques set forth in Krueckeberg and Silvers, Urban Planning Analysis: Methods and Models (20). For those unfamiliar with PERT and Critical Path Management (CPM) (a related tool), this volume can provide excellent guidance and additional references and is highly recommended.

Based on Monroe County's experience in applying the method, the Demonstration Model can be adapted for use by each particular study team. The nature of that use will depend on the technical expertise of the study team and the available resources. The model has been constructed to anticipate variability in both of these factors. On a basic level, the model can be easily adapted to construct a simple flow diagram. For study teams familiar with PERT, the model can be used in its current form, with specific activities, linkages, and time estimates respecified as necessary. The model can also be expanded according to the techniques of CPM. Employing CPM would allow for the cost-efficient scheduling and allocation of resources for the study. Study teams with PERT programming capability will find the Demonstration Model readily adaptable to the computer (e.g., dummy activities are incorporated in the model to allow the computer to distinguish between parallel activities).

PERT: A Basic Description

To understand PERT, it may be helpful for those unfamiliar with the technique to view the PERT diagram (Figure A-1) as analagous to a road map. Beginning from the left hand side of the diagram at Event 1, one imagines the study team travelling as a group down the first path. This path corresponds to Activity A in Table A-1. The end of activity A is represented by the teams arrival at Event 2. At Event 2, however, there are two divergent paths (B And C). At this point, the study team has two concurrent tasks to perform (called parallel activities). Using the road map analogy, part of the team is engaged in Activity B (the proverbial high road) and the rest of the study team is engaged in Activity C (the proverbial low road). The arrival of both groups at Event 4 (the proverbial Scotland) is necessary before the team can begin Activity D.

The true purpose of PERT then becomes clear. By systematically defining each distinct path and the order in which they must be travelled, study planners can anticipate "Slack Time" at any given event (i.e., how long the group travelling the low road must wait for the group travelling the high road). Defining Slack Time at each event allows the study planners to arrange the timely hiring of staff and the efficient distribution and timing of specific tasks. PERT also provides the expected value and probability distributions for the duration of the project. The estimation and comparison of costs incurred during Slack Time and costs required to speed up ("crash") an activity is the basis for CPM.

PERT Demonstration Model

This section describes the PERT Demonstration Model and the general procedure used to derive it. First, a number of relevant assumptions and characteristics of the model are presented. In addition, this list contains several suggestions which should further facilitate the reader's understanding of the model.

- The model is based on the actual procedure followed by Monroe County, with minimal rescheduling of activities (a normal part of PERT applications). This was to facilitate careful consideration and respecification of the model by each study team.

- The part of the overall study that the model (and the results) correspond to is from the original inception of the project to the completion of the study for the first municipality. Activities A to N and P correspond to the entire study area, whereas activities O and Q to LL are for the first municipality.

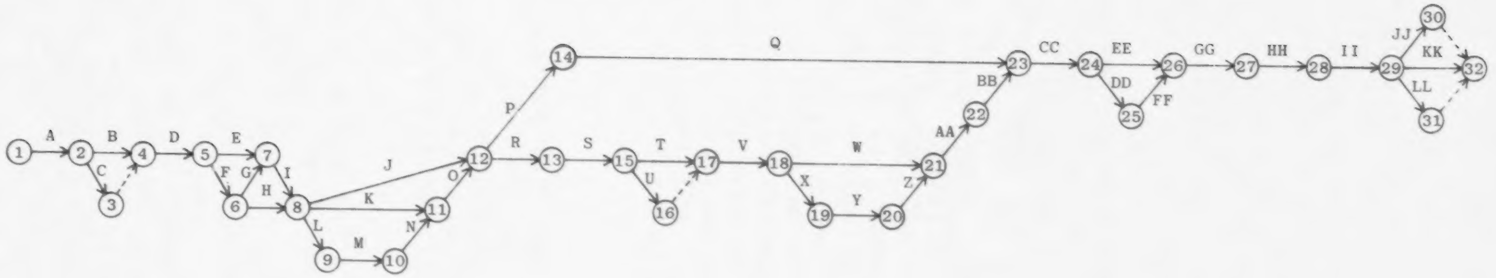
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Figure A-1. PERT demonstration model.

TABLE A-1. COMPONENT ACTIVITIES AND TIME ESTIMATES FOR PERT DEMONSTRATION MODEL

		Time Estimates (days)					
	Activity	a	m	b	t_e	σ	σ^2
(A)	Formulate study goals	1	2	3	2.0	0.3	0.1*
(B)	Identify state and local government agencies with regulatory or review responsibilities pertaining to solid waste management	1	2	3	2.0	0.3	0.1
(C)	Identify other agencies, groups, and individuals with relevant interests	2	5	10	5.3	1.3	1.8*
(D)	Form study committee	7	28	42	26.8	5.8	34.0*
(E)	Secure funding	42	90	180	97.0	23.0	529.0*
(F)	Identify agency to conduct study	7	14	28	14.2	4.5	20.3
(G)	Develop specific study plan	7	21	42	22.2	5.8	34.0
(H)	Identify aerial photograph, map, and information resources	10	21	56	25.0	7.7	58.8
(I)	Allocate responsibilities to existing staff; arrange to hire consultants	3	14	28	14.5	4.2	17.4*
(J)	Collect geologic maps and information	21	90	180	93.5	26.5	702.3
(K)	Collect aerial photographs, orthophotomap index	3	14	42	16.8	6.5	42.3
(L)	Collect current USGS topographic maps	1	14	90	24.5	14.8	220.0*

	Time Estimates (days)					
Activity	a	m	b	t_e	σ	σ^2
(M) Collect information on known sites from existing sources	28	90	180	94.7	25.3	641.8*
(N) Conduct call-in campaign	28	42	56	42.0	4.7	21.8*
(O) Interpret and annotate aerial photographs	1	4	7	4.0	1.0	1.0*
(P) Develop preliminary regional hydrogeologic model	7	28	180	49.8	28.8	831.4
(Q) Compile/modify relevant geologic maps and profiles	7	14	28	15.2	3.5	12.3
(R) Obtain orthophotomaps covering identified sites	7	21	60	25.2	8.8	78.0*
(S) Record maximum site boundaries on orthophotomaps	7	10	21	11.3	2.3	5.4*
(T) Prepare general survey map	1	2	3	2.0	0.3	0.1
(U) Specify preliminary rankings for site activity and land use	1	2	7	2.7	1.0	1.0*
(V) Prepare municipal map	1	2	3	2.0	0.3	0.1*
(W) Review agency records and reports, directories, and surveys	7	14	28	15.2	3.5	12.3
(X) Field check sites to confirm/modify land use ranking	1	2	4	2.2	0.5	0.3*
(Y) Interview senior municipal administrative official	1	3	7	3.3	1.0	1.0*

	Activity	Time Estimates (days) a	m	b	t_e	σ	σ^2
(Z)	Interview municipal engineer, fire marshal, building inspector, police chief, historian; conservation officers; other law enforcement officers; local chambers of commerce; utility personnel; waste haulers; public works agency personnel; industrial organization personnel; residents	7	14	21	14.0	2.3	5.4*
(AA)	Interview specific industry personnel	7	14	21	14.0	2.3	5.4*
(BB)	Confirm/modify site activity rankings; compile list of confirmed waste disposal sites; revise municipal map	1	3	7	3.3	1.0	1.0*
(CC)	Locate public/private/individual drinking water supplies	7	21	35	21.0	4.7	21.8*
(DD)	Complete site-specific hydrogeologic analysis and establish preliminary geologic ranking for sites near water supplies	1	2	3	2.0	0.3	0.1*
(EE)	Complete site-specific hydrogeologic analysis and establish preliminary geologic ranking for remaining sites	1	2	3	2.0	0.3	0.1
(FF)	Establish preliminary rankings of water supplies for contamination potential	1	2	3	2.0	0.3	0.1*

		Time Estimates (days)					
	Activity	a	m	b	t_e	σ	σ^2
(GG)	Confirm/modify geologic rankings of water supplies and sites using field checks if necessary	1	2	3	2.0	0.3	0.1*
(HH)	Construct matrix to determine site rank	1	2	3	2.0	0.3	0.1*
(II)	Establish priorities for further investigation	1	2	3	2.0	0.3	0.1*
(JJ)	Publish site inventory report	14	21	42	23.3	4.7	21.8*
(KK)	Notify landowners, well owners	2	4	7	4.2	0.8	0.7
(LL)	Refer sites to appropriate agency for action	2	4	7	4.2	0.8	0.7

* denotes an activity on the Critical Path in the demonstration model

Calculations:

a = optimistic time estimate (shortest result in 100 trials)

m = modal time estimate (most frequent result in 100 trials)

b = pessimistic time estimate (longest result in 100 trials)

t_e = expected time = $\frac{a + 4m + b}{6}$

σ = standard deviation from expected time = $\frac{b - a}{6}$

- The authors suggest that it would be most expedient for the study planners to select for initial study a municipality with readily available information and map resources.

- Since activities O and Q to LL must be repeated for each of the remaining municipalities, it is suggested that a new PERT model (which may be easily derived from the Demonstration Model) be specified so that the scheduling and allocation of resources for the study of the remaining municipalities may be determined.

- It was assumed always that a particular activity leading up to an event had to be entirely completed before subsequent activities could be started. This is clearly not always the case in reality. For example, it is not necessary to have all of the aerial photographs for the study area collected (activity K in the model) before photointerpretation (activity O) can begin. This is generally one of the few drawbacks of PERT (or at least of this particular model). However, a creative respecification of the model may well resolve this not-too-serious problem.

- In estimating the duration of the activities, the authors felt it would be most useful to assume a situation similar to that confronting the reader (i.e., no prior experience applying the method, but having this report as a planning tool).

- Time estimates were based on a study area of the size and population of Monroe County (central city with 19 surrounding municipalities, population 700,000); variability in the availability of resources (e.g., USGS topographic maps); and staff resources consisting of a project director, one staff research assistant, one consulting hydrogeologist, and one consulting air photointerpreter.

- It was assumed that no activity would take less than one day.

- The assignment of numbers to events is arbitrary and does not necessarily reflect the order in which events are arrived at.

- Study planners should transfer Figure A-1 to a larger sheet of paper. Expanding the diagram will allow the replacement of the letter codes with the actual written descriptions of the activities from Table A-1 and the addition of the time estimates from Table A-2.

- The main text of the report should be read carefully for detailed descriptions of the activities.

The Demonstration Model is depicted in Figure A-1, and the relevant data are presented in Tables A-1 and A-2. The following description of the model derivation procedure and the results are presented for further clarification. The separate subject headings correspond to the steps of the derivation.

Define activities:

All of the separate tasks performed by the study team were defined and listed (Table A-1).

Sequence activities:

A complete list of specific activity sequences was compiled. For example, it was necessary to form a study committee (activity D) before identifying a specific agency to conduct the study (activity F). This was represented in the list as:

$$\xrightarrow{D} \quad \xrightarrow{F}$$

The PERT diagram represents the network constructed on the basis of these linkages. The observant reader will have noticed that there is a dashed arrow running from Event 3 to Event 4 (also from Events 16 to 17 and 31 to 32). This arrow denotes a dummy activity. Dummy activities are not real activities. Taking neither time nor resources, they simply provide a way of distinguishing Path B from Path C in terms of events (i.e., Path B corresponds to 2 - 4, Path C corresponds to 2-3-4). This is to facilitate adaptation of the model to a PERT computer program.

Activity duration estimation:

Once the basic PERT model was constructed, estimates were obtained for the expected duration of each activity. The expected duration of each activity was derived mathematically from three separate estimates: an optimistic time estimate (a), a modal time estimate (m), and a pessimistic time estimate (b). Krueckeberg and Silvers provide the following definitions of each:

- the optimistic estimate (a) is the time the activity would take "under the best of luck and conditions--having a probability of about one out of 100;"

TABLE A-2. EVENTS AND TIME ESTIMATES FOR PERT DEMONSTRATION MODEL

Event	T_E	T_L	Slack	Event	T_E	T_L	Slack
1	0	0	0	17	350.0	350.0	0
2	2.0	2.0	0	18	352.0	352.0	0
3	7.3	7.3	0	19	354.2	354.2	0
4	7.3	7.3	0	20	357.5	357.5	0
5	34.1	34.1	0	21	371.5	371.5	0
6	48.3	108.9	60.6	22	385.5	385.5	0
7	131.1	131.1	0	23	388.8	388.8	0
8	145.6	145.6	0	24	409.8	409.8	0
9	240.3	240.3	0	25	411.8	411.8	0
10	264.8	264.8	0	26	413.8	413.8	0
11	306.8	306.8	0	27	415.8	415.8	0
12	310.8	310.8	0	28	417.8	417.8	0
13	336.0	336.0	0	29	419.8	419.8	0
14	347.3	347.3	0	30	443.1	443.1	0
15	360.6	373.6	13.0	31	424.0	443.1	19.1
16	350.0	350.0	0	32	443.1	443.1	0

T_E = Earliest expected arrival time (days)

T_L = Latest allowable leaving time (days)

- the modal estimate (m) is the time the activity will require most frequently if it were conducted many times "under randomly varying conditions;" and

- the pessimistic estimate (b) is the length of time the activity will take "under the worst of luck and conditions--having a probability of about one out of 100."

From the basis of these specific estimates, a single value for the expected duration of the activity (t sub-e) was defined. Also, since we were interested in the expected deviations from that value, the standard deviations of each estimate were calculated (sigma). The formulas used for the calculation of t sub-e and sigma are presented at the end of Table A-1.

Establish earliest expected arrival times for each event:

The earliest expected arrival time (T sub-E) is obtained by summing up the expected activity durations (t sub-e) for each different sequence of activities leading up to that event. The arrival time assigned to the event is the latest arrival time derived from each of the activity sequences leading to that event.

Establish latest allowable leaving times for each event:

Next, the latest allowable leaving time (T sub-L) was defined for each event. Again using the road map analogy, this is the latest time that the reconvened study team can leave a particular event without delaying the entire project. The best way to illustrate its calculation is with an example. The T sub-L assigned to Event 19 equals the T sub-E of Event 20 minus the t sub-e of the activity running between Event 19 and Event 20. Using the values from Tables A-1 and A-2, we obtain:

T sub-L(Event 19) = 357.5(T sub-E, 20) - 3.3(t sub-e, Y)
= 354.2

Define Slack Time:

Slack Time (S) was defined for each event. S equals T sub-L minus T sub-E for that event. For example, for Event 6:

S(Event 6) = 108.9(T sub-L, 6) - 48.3(T sub-E, 6)
= 60.6

Whenever there is Slack Time at an event, the study planners should reconsider the timing of the performance of the relevant tasks or, if the timing is unalterable--e.g., due to contract obligations or unalterable parallel activities--the planners should weigh the relative costs of Slack Time efficiency losses and speeding up the slower activity. Again, the reader is reminded of the suitability of CPM for this purpose.

Define critical path:

The critical path (CP) is the sequence of paths with (a) the longest elapsed time, and (b) the lowest total Slack Time. It is this path (or paths, for there can be more than one at a time) which determines the duration of the entire project. Any delays in activities on a critical path will delay the completion of the project. For the demonstration model, the CP was found to be:

1-2-3-4-5-7-8-9-10-11-12-13-15-16-17-18-19-20-21-22-23-24-25-26-27-28-29-30-32

The resulting time estimate for the duration of the project was 443.1 days, rounded off to 443 days (or 63.3 weeks). It is important to remember that this is the time expected to elapse between the inception of the project and the completion of the procedure for the first municipality.

Project duration probability distribution:

It is often useful to provide some estimate of the variability to be expected in the duration of the project. It is for this purpose that we calculated the standard deviation from the expected duration of each activity. Only activities along the CP are incorporated in the calculation. The values for sigma-squared for CP activities are marked with an asterisk in Table A-1. To calculate the standard deviation from the expected duration of the entire project (443 days), the following formula was used:

$\sigma(\text{project}) = (\Sigma o_i^2)$ where i = each CP activity

For the demonstration model, then, the values marked with an asterisk in Table A-1 were summed and the square root was taken. The resulting value, 40.1 days, was rounded to 40 days. Employing a Bayesian interpretation of this result, the project in its current unmodified form would be expected to take between 403 and 483 days to complete 68%, or roughly two-thirds, of the time. The other one-third of the time, the project would be expected to take less than 403 days or more than 483 days.

If we want to establish a higher level of certainty, we must accept a broader estimation interval. For example, if we wished to define an interval which we expect to contain the actual result 95% of the time, we must add and subtract two standard deviations from the expected duration of the project. In the demonstration case, we can say that (again returning to a Bayesian interpretation) 95% of the time, we expect the project will take from 363 to 523 days to complete (this is 443 plus or minus 2 x 40 days).

It is possible that more than one CP will emerge. In fact, this would tend to indicate a higher degree of scheduling efficiency since there is probably less overall Slack Time. The normal procedure, in this case, is to use the CP with the wider duration probability distribution to determine the confidence interval of the project.

Some Final Words on Model Respecification

Slack Time was found at Events 6, 15, and 31. Clearly, there is room for respecification of the procedure. For example, Activity L on the CP, the collection of USGS topographic maps, is expected to take 24.5 days. The optimistic estimate is based on the previous availability of the maps. The pessimistic estimate assumes a serious backlog of map orders at the Geological Survey (which is common in September as many schools order maps for fall geology courses). The CP can be shortened by 24.5 days if, during Activity H, the identification of resources, the order for topographic maps is placed if they are not already available. Again, the Demonstration Model is based on Monroe County's actual experience, rather than how it would have been done were Monroe County to try it again.

In order to arrange the efficient rescheduling of the project, it will be necessary to define slack time for each activity (which we will call Idle Time to distinguish it from normal Slack Time). For example, look at Activities B and C in the Demonstration Model. Although Events 2,3, and 4 all show no Slack Time, we know by looking at the model that Activity B is expected to be finished in only 2.0 days, while Activity C is expected to require 5.3 days to complete. This means that, although no Slack Time emerged, those involved in Activity B will be idle for 3.3 days waiting for those involved in C to complete their work.

The study team should look for Idle Time in each non-CP activity. Idle Time can be determined by subtracting the T sub-L of the activity's starting event from the T sub-L of the activity's ending event. If the t sub-e of the activity is then subtracted from this number, Idle Time for that activity is obtained. Options for reallocating resources and rescheduling activities can then be assessed with the intention of shortening the CP.

APPENDIX B

ADDRESSES OF PROJECT RESOURCES

Aerial Photographs

Computerized indices for all USGS, NASA, and satellite photography

EROS Data Center
Sioux Falls
SD 57198

USGS Photography (ordered from EROS Data Center, above) includes orthophotoquad maps (1:24,000) which may be useful for filling in missing photo data or as base maps. Orthophotoquad maps can be ordered from the National Cartographic Information Center, Reston, VA (see address below).

County and Strip Coverage

U.S. Department of Agriculture
Green Belt, Maryland and Salt Lake City, Utah Repositories

NASA Skylab (5" format), high altitude U-Z or RB-57 aircraft photography. (order from EROS Data Center)

U.S. Army Corps of Engineers District Offices

State Departments of Transportation (NYSDOT has a comprehensive county index issued in 1979)

Coastal or Near Coastal Areas

National Ocean Survey
Photogrammetry Division
National Ocean Survey, NOAA
Rockville, MD 20852

Flood hazard areas and miscellaneous projects

Federal Emergency Management Agency
90 Church St.
New York, NY 10007

National Cartographic Information Center has miscellaneous coverage indexed by state, as well as orthophotoquad maps:

National Cartographic Information Center
U.S. Geological Survey
507 National Center
Reston, VA 22092

National Archives and Records Service has photos from 1934 to 1942. Free catalog on request.

Cartographic Archives Division
National Archives and Records Service
General Services Administration
Washington, DC 20408

U.S. Forest Service (as available for specific National Forest areas)

U.S. Bureau of Reclamation (as available for specific project regions)

Private Commercial Aerial Photography Firms (see yellow pages of telephone directory)

Colleges and Universities (miscellaneous collections in divisions or departments)

City or County Planning Agencies or Environmental Management Councils

Real Property Tax Offices or Departments

Agriculture Extension Service, Soil Conservation Service, and Agricultural Stabilization and Conservation Service

U.S. Government Maps

Current Editions of topographic and geologic maps

East of the Mississippi:
Branch of Distribution
U.S. Geological Survey
1200 South Eads St.
Arlington, VA 22202

West of the Mississippi:
Branch of Distribution
U.S. Geological Survey
Box 25286 Federal Center
Denver, CO 80225

Older Editions of topographic and geologic maps
(micro film and special products)

National Cartographic Information Center
U.S. Geological Survey
507 National Center
Reston, VA 22092

Soil Maps

U.S. Department of Agriculture
Local Office, Soil Conservation Service

U.S. Government Publications

U.S. Government Printing Office
Washington, DC 20402

National Technical Information Service
Springfield, VA 22161

APPENDIX C

CALL-IN CAMPAIGN FORM

Monroe County Landfill Review Committee
Old Dump Sites
telephone call form

Date Call Received ____________________ Call Received By ____________________

Caller Information ____
name telephone #

____
mailing address & zip code

Dump Information ____
city or town location

____
street or road location

____
year or years dump used

____
materials deposited at dump

____
is dump still used?

Additional Comments ____
About Dump ____

____

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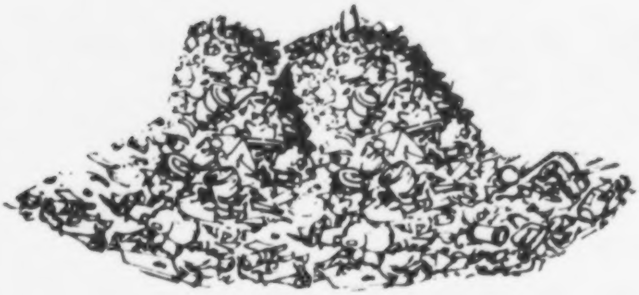
Draft Form Used in Monroe County, New York

APPENDIX D

CALL-IN CAMPAIGN FLYER

Monroe County is trying to find old dump sites....



DO YOU KNOW ABOUT ANY ?

IF SO, CALL THE MONROE COUNTY HEALTH DEPARTMENT AT 442-4000.

WE'RE WORKING WITH A NUMBER OF COUNTY AND STATE AGENCIES TO IDENTIFY THE LOCATIONS OF OLD DUMPS IN MONROE COUNTY THAT COULD POSE PUBLIC HEALTH PROBLEMS. WE ARE PRIMARILY INTERESTED IN DUMPS USED BEFORE 1960 AND BACK TO AROUND THE TURN OF THE CENTURY.

THE KIND OF INFORMATION WE NEED IS:

- **WHERE** WAS THE DUMP LOCATED ?
  CITY OR TOWN; STREET OR ROAD
- **WHEN** WAS THE DUMP USED ?
  APPROXIMATE YEARS
- **WHAT** TYPES OF MATTER WERE DUMPED ?
  HOUSEHOLD TRASH, AGRICULTURE OR INDUSTRIAL WASTE

PLEASE CALL US IF YOU HAVE SUCH INFORMATION BEFORE THE END OF MAY, 1979.
DIAL 442-4000 AND ASK FOR EXTENSION 2882.

JOEL L. NITZKIN, M.D.
COUNTY HEALTH DIRECTOR

APPENDIX E

SITE ACTIVITY RECORD AND GUIDE FOR COMPLETING THE FORM

These pages serve as a guide to completing the Site Activity Record (SAR).

The site summary in the upper right hand corner of the first page identifies key information.

- Quadrangle No. refers to the number assigned to the particular USGS quadrangle map in which the site is found. (These numbers are assigned to each quadrangle map at the beginning of the study for reference purposes.)
- Planimetric Map No. and Orthophoto No. refer to the numbers found on the map sheets.
- Site Activity refers to the five categories of dump/landfill (D), possible dump/landfill (P), unspecified fill (U), lagoon (L), or junkyard (J) defined in Table 2-2.
- Geology is ranked .01, .02, or .03 depending on the score the site receives on the Geologic Ranking Sheet described in Figure 5-1.
- Land Use is ranked .01, .02, .03, .04, .05, or .06 as described in Table 2-3.
- Water Supply Contamination Potential is ranked .01 or .02 as shown in Table 3-1, Stage 2.

The description below correspond to numbers on the SAR.

5. Record activity noted on each year of photography along with the appropriate aerial photo numbers (Chapter 2).
6. An estimate of site acreage is most easily obtained by developing a standard grid to lay over the maximum boundary delineated on the orthophoto-or planimetric maps.
7. Land use activities can be shown on either a 1"=200' orthophoto-or planimetric map or a small scale site sketch map. Since the orthophotomaps and some planimetric maps show building locations, these maps can be used to provide some indication of the

populations that could be impacted. They are also at an excellent scale for recording house numbers and water supply locations. (See item 19.) General criteria for distinguishing between known dumping/landfilling, possible dumping/landfilling, etc. can be found in Table 2-1.

8. Type of Waste: This is general information obtained from existing records and interviews with local officials, industrial representatives, waste haulers, or the general public.

9. Current Site Owner: Obtain from tax records.

10. Previous Owners: Search deed records

11. Site Operator: Research municipal, county, or state records or contact site owner.

12. Haulers Using Site: Records or interviews.

13. Municipalities/Industries/Commercial Establishments Using Site: Records or interviews.

14. See item 7 for a discussion of maps.

15. Noteworthy Current Land Use Information should be obtained from the most recent aerial photographs and verified for confirmed dumps/landfills by field checks. Any major facilities on or adjacent to the site should be noted.

16. Contact local planning departments or zoning boards to determine zoning.

17. Estimate the number of buildings/homes within 1000 feet using the orthophotomap or the most recent aerial photographs.

18. The Site Impact Data Sheet is the fifth page of the SAR.

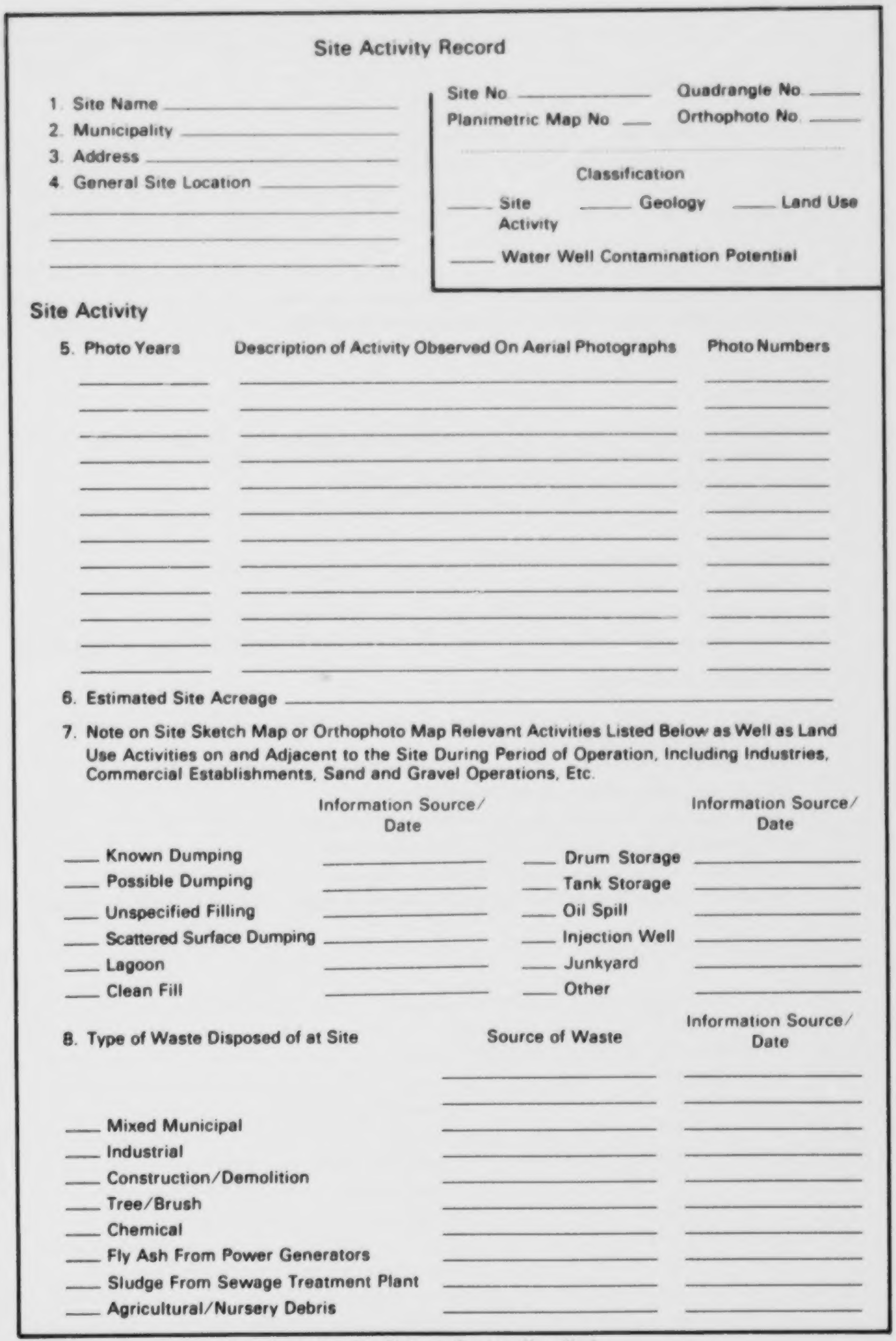
19. To locate individual water wells, draw a line 1000 feet from the perimeter of the maximum boundary as depicted on the orthophotomap. Check addresses for water service (Chapter 3). Increase the line to 2000 feet from the site boundary for high volume sites over 20 acres.

20. Private water supply systems serve less than 25 individuals and are usually associated with restaurants, golf courses, mobile home parks, camps, or industries. The location of these supplies can be determined through local health department records.

21. Information on surface drinking water supplies should be available through local health department records.

22-30. This section should be completed by the hydrogeologist associated with the project. Item 29 should include information on the potential impact on streams, wetlands, wildlife, etc.

31-36. All documentation from supplementary sources should be added to this section. The additional information section (item 36) may include data from a variety of documents, including street or business directories, plat books, fire insurance maps, and hazardous waste publications (see the checklist on the fourth page of the SAR).



Site Activity Record

1. Site Name ____
2. Municipality ____
3. Address ____
4. General Site Location ____

Site No. ____ Quadrangle No. ____

Planimetric Map No. ____ Orthophoto No. ____

Classification

____ Site Activity ____ Geology ____ Land Use

____ Water Well Contamination Potential

Site Activity

5. Photo Years	Description of Activity Observed On Aerial Photographs	Photo Numbers

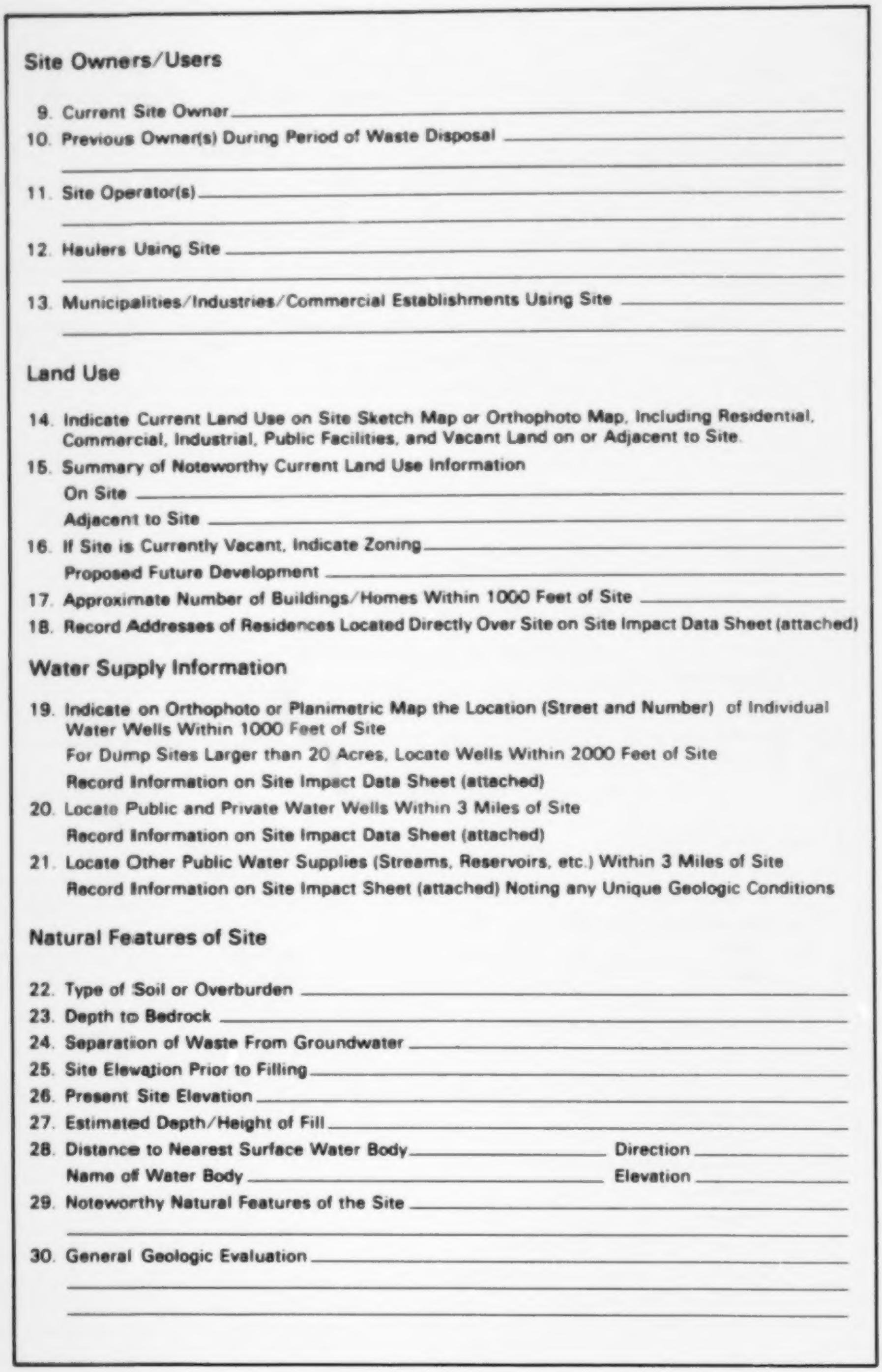
6. Estimated Site Acreage ____

7. Note on Site Sketch Map or Orthophoto Map Relevant Activities Listed Below as Well as Land Use Activities on and Adjacent to the Site During Period of Operation, Including Industries, Commercial Establishments, Sand and Gravel Operations, Etc.

	Information Source/ Date		Information Source/ Date
____ Known Dumping		____ Drum Storage	
____ Possible Dumping		____ Tank Storage	
____ Unspecified Filling		____ Oil Spill	
____ Scattered Surface Dumping		____ Injection Well	
____ Lagoon		____ Junkyard	
____ Clean Fill		____ Other	

8. Type of Waste Disposed of at Site	Source of Waste	Information Source/ Date
____ Mixed Municipal		
____ Industrial		
____ Construction/Demolition		
____ Tree/Brush		
____ Chemical		
____ Fly Ash From Power Generators		
____ Sludge From Sewage Treatment Plant		
____ Agricultural/Nursery Debris		

Draft Form Used in Monroe County, New York



Site Owners/Users

9. Current Site Owner ____________________
10. Previous Owner(s) During Period of Waste Disposal ____________________
____
11. Site Operator(s) ____________________
____
12. Haulers Using Site ____________________
____
13. Municipalities/Industries/Commercial Establishments Using Site ____________________
____

Land Use

14. Indicate Current Land Use on Site Sketch Map or Orthophoto Map, Including Residential, Commercial, Industrial, Public Facilities, and Vacant Land on or Adjacent to Site.
15. Summary of Noteworthy Current Land Use Information
On Site ____________________
Adjacent to Site ____________________
16. If Site is Currently Vacant, Indicate Zoning ____________________
Proposed Future Development ____________________
17. Approximate Number of Buildings/Homes Within 1000 Feet of Site ____________________
18. Record Addresses of Residences Located Directly Over Site on Site Impact Data Sheet (attached)

Water Supply Information

19. Indicate on Orthophoto or Planimetric Map the Location (Street and Number) of Individual Water Wells Within 1000 Feet of Site
For Dump Sites Larger than 20 Acres, Locate Wells Within 2000 Feet of Site
Record Information on Site Impact Data Sheet (attached)
20. Locate Public and Private Water Wells Within 3 Miles of Site
Record Information on Site Impact Data Sheet (attached)
21. Locate Other Public Water Supplies (Streams, Reservoirs, etc.) Within 3 Miles of Site
Record Information on Site Impact Sheet (attached) Noting any Unique Geologic Conditions

Natural Features of Site

22. Type of Soil or Overburden ____________________
23. Depth to Bedrock ____________________
24. Separation of Waste From Groundwater ____________________
25. Site Elevation Prior to Filling ____________________
26. Present Site Elevation ____________________
27. Estimated Depth/Height of Fill ____________________
28. Distance to Nearest Surface Water Body ____________ Direction ____________
Name of Water Body ____________ Elevation ____________
29. Noteworthy Natural Features of the Site ____________________
____
30. General Geologic Evaluation ____________________
____
____

Supplementary Information Sources

31. Agency File Information ______________________________

32. Permits for Site ______________________________

33. Interview Information ______________________________

34. Call-In Information ______________________________

35. Field Inspection Remarks ______________________________

36. Additional Information ______________________________

Final Recommendations

____

Information Sources Checklist

Source	Contact/Document	Date
___ Aerial Photographs		
Agency Files		
___ DEC		
___ Health Department		
___ Planning Department		
___ Atlases		
___ Boring Logs		
___ Business Directories		
___ Call-In Information		
___ Deeds, Tax Records		
___ Field Inspection		
___ Government Publications Relating to Hazardous Waste		
___ Historic Sources		
___ Industry Files		
Interviews		
___ Local Officials		
___ Conservation Board		
___ Residents		
___ Industry Officials		
___ Plat Books		
___ Sanborn Fire Insurance Maps		
___ Site Permits		
___ Soil Maps		
___ Street Directories		
___ Water Billing Records		

Municipality Contacts Checklist

Contact	Name	Date
Supervisor		
Building Inspector		
Engineer		
Historian		
Commissioner of Public Works		
Highway Supervisor		
Police Chief		
Fire Marshal		
Conservation Board Chairperson		
Conservation Board Members		
Other		

Site Impact Data Sheet

Names and Addresses of Residents Located Directly Over Site	Date Owner Notified

Individual Wells Within 1000 Feet of Site

Name of Resident and Address for Water Well	Well Depth	Type of Aquifer (Overburden, Bedrock)	Well Contamination Potential	Date Owner Notified

Individual Water Wells Within 2000 Feet of Site (for sites larger than 20 acres)

Name of Resident and Address for Water Well	Well Depth	Type of Aquifer (Overburden, Bedrock)	Well Contamination Potential	Date Owner Notified

Public and Private Water Wells Within 1/2 Mile of Site

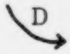
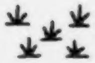
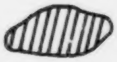
Name of Facility and Address for Water Well	Well Depth	Type of Aquifer (Overburden, Bedrock)	Well Contamination Potential	Date Owner Notified

Public and Private Water Wells Within 3 Miles of Site

Name of Facility and Address for Water Well	Well Depth	Type of Aquifer (Overburden, Bedrock)	Well Contamination Potential	Date Owner Notified

APPENDIX F

SYMBOLS FOR NOTATION ON AERIAL PHOTOGRAPHS

D	WASTE DISPOSAL
P	POSSIBLE WASTE DISPOSAL
F	FILLING
CF	CLEAN FILL
JY	JUNKYARD
S/G	SAND AND GRAVEL EXCAVATION AREA
S/Ga	ABANDONED SAND AND GRAVEL AREA
St	STOCKPILES
Id Ind	IDENTIFY INDUSTRY
	DRAINAGE
ditch ↔	DITCH
	WETLAND
	PONDED WATER
Ⓔ	ELIMINATE SITE

APPENDIX G

Waste Disposal Site Information Sheet
Monroe County, New York

Municipality:	
Site Number:	
Location:	
Type of Disposal:	
Current Owner(s):	
Operators/Users During Period of Activity:	
Type of Waste:	____ Municipal ____ Tree/Brush ____ Construction/ Demolition ____ Sludge from Sewage Treatment Plant ____ Chemical ____ Industrial ____ Fly Ash from Power Generators ____ Agricultural/Nursery Debris ____ Other Type ____________
Period of Operation:	
Acreage:	
Individual Water Wells Within 1000 Feet of Site Boundaries:	____ Yes ____ No
Public/Private Water Supply Systems Within 1/2 Mile of Site Boundaries	
Current Land Use on Site:	
Special Comments:	
Date of Report:	

Information contained on this sheet is preliminary and subject to further refinement.
Report prepared by the Monroe County Environmental Management Council.
Draft Form Used in Monroe County, New York

APPENDIX H

NOTIFICATION LETTER TO INDIVIDUAL WELL OWNER

Date

Dear Sir:

The County Health Department has been working with state and local agencies to survey active and inactive waste disposal sites in the county.

Our search of records and our analysis of aerial photos indicates the presence of a site within 1000 feet of your home.

Since waste disposal sites may adversely affect the quality of water in nearby wells, you may wish to consider connecting to a public water supply system, installing an on-site water treatment system, or using bottled water for drinking and cooking.

To assist us in completing this survey, please contact my office at 555-5555, extension 555, to confirm whether there is a well on your property that is used for drinking water. I will be glad to answer any questions you may have about this program.

Sincerely,

Director
County Health Department

cc: concerned agencies

APPENDIX I

NOTIFICATION LETTER TO LANDOWNER

Date

Dear Sir:

During the last three years the County Environmental Management Council and the County Health Department have been working with concerned state and local agencies to identify and classify active and inactive waste disposal sites in the county to determine what effect they might have on county residents.

Attached is a description of a site you currently own which has been used for waste disposal in the past. This information is contained in a report, "Inventory of Active and Inactive Waste Disposal Sites," prepared by the County Landfill Review Committee. The report has been forwarded to the State Department of Environmental Conservation in accordance with Article 55, Section 5555 of the State Environmental Conservation Law. Follow-up investigations may be conducted by the State Department of Environmental Conservation and/or the State Health Department.

Please review the data and, if you can be of assistance to us in our attempt to complete this survey or if you have any questions, please call my office at 555-5555, extension 555.

Sincerely,

Director
County Health Department

cc: concerned agencies

APPENDIX J

A GEOLOGIC CASE STUDY FOR AN INDUSTRIAL LANDFILL

INTRODUCTION

This case study illustrates how the geologic information discussed in this report was applied to the investigation of an industrial landfill in Monroe County. The landfill, owned by the Eastman Kodak Company, currently operates under permit from the New York State Department of Environmental Conservation (DEC). When the Monroe County Landfill Review Committee (LRC) first began to review the site in detail, they suspected that waste disposal previously had occurred over a wider area than the current operation. No public records were available to detail the boundaries, contents, or waste disposal practices of any earlier activity. To substantiate this belief, the committee utilized aerial photographs and other records to confirm that the Weiland Road Industrial Landfill had existed since the late 1940's.

Due to the scarcity of aerial photography during the 1940's, the first documented dumping was noted on 1951 photographs. This activity occurred at the eastern end of the site. Borrow operations and grading expanded westward during the 1960's. By 1975 the dumping on the eastern two-thirds of the site had been covered and the area converted to parking lots, roadways, and recreational facilities (Figure J-1). While only one-third of the site is presently active, a total area of approximately 45 acres has been involved since the earliest recorded activity.

The aerial photographs also provided information on site drainage and identified a wetland that existed prior to waste disposal activity on the southwest portion of the site. According to old engineering drawings and records furnished by Kodak, the stream draining the site was gradually filled in, but a shallow, buried french drain was extended along its former course as landfilling continued in a generally westward direction. In the 1950's a chlorination station was installed along the drain system to correct odor problems in response to complaints from local residents.

In 1979 an ad hoc committee of the newly created Monroe County LRC began to take a close look at both the past and present disposal activity at the site. The ad hoc committee

Figure J-1. Aerial photographs of the Weiland Road industrial landfill (1963 and 1975). A. View of site during early stage of development (1963). B. View of site as it appeared in 1975. See Figure J-2 for maximum boundary of waste disposal.

included representatives from the DEC, the Monroe County Department of Health, and the Monroe County Environmental Management Council (EMC). The study's consulting geologist participated with the group in analyzing the information.

When the committee began evaluating the site, Kodak had an application pending with the DEC for a permit to move the chlorination station and extend the existing drains to the northwest corner of the site. Shortly thereafter Kodak decided to connect the drains to the company's industrial sewage treatment plant. The LRC's geologist was concerned that leachate could still move off the site in a northwesterly direction through soils beneath the drains. In fact, the committee knew that contaminated groundwater was moving in this direction because tests conducted in 1979 by the Monroe County Health Department detected acid magenta in a private water well on the northwest corner of the site.

The LRC began by gathering information on site boundaries and drainage, and by interpretating available aerial photography from 1930 to the present. This information permitted the LRC to document the maximum boundary of the site as well as pre-existing site drainage without access to company records. (Figure J-2). This information was supplemented by records and permit applications in the DEC files, as well as Monroe County Health Department inspection reports.

The LRC's consulting geologist prepared a preliminary geologic report on the site and meetings were held with company officials to verify the committee's findings and to obtain additional information, including site contents. These meetings clarified aerial photointerpretations concerning extraction activities, resulted in Kodak sharing with the committee photographs of the site taken by low flying aircraft, and revealed a new set of boring logs from a recent county highway project on the west end of the disposal area (Figure J-2). These borings proved to be invaluable in confirming the subsurface geology. A revised geologic report was prepared by the committee's geologist, documenting loose sands and gravels at depth on the west end of the site. Further meetings were held with Kodak personnel to discuss the committee's documentation of the potential for leachate to migrate westward off the site.

These concerns were also addressed in a monograph on the Weiland Road site published by the LRC in June 1980 (21). This report included a summary of the committee's investigation and a recommendation that further testing down to the bedrock surface be completed to determine if leachate was migrating below the

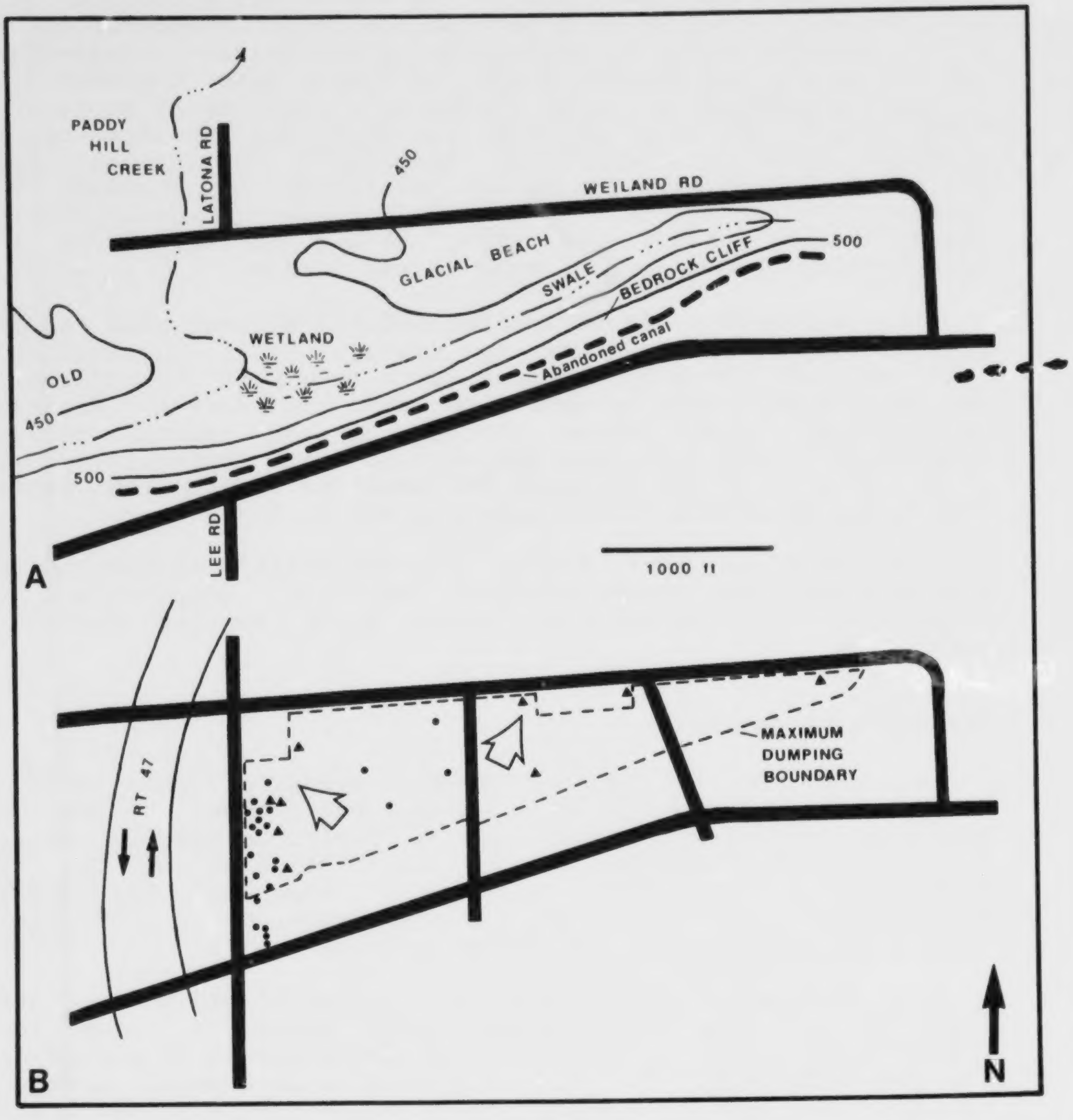

PADDY
HILL
CREEK
LATONA RD
450
WEILAND RD
GLACIAL BEACH
SWALE
BEDROCK CLIFF
500
WETLAND
OLD
450
Abandoned canal
500
LEE RD
1000 ft
A
RT 47
MAXIMUM
DUMPING
BOUNDARY
B
N

Figure J-2. Weiland Road industrial landfill. A. Topography and geologic features of site prior to urbanization. Contour interval 50 feet. B. Maximum boundary of waste disposal through 1975 with additional road construction. Black dots indicate borings located for highway construction and engineering projects. Triangles are new groundwater monitoring wells completed as a result of recommendations following preliminary study. Large arrows indicate groundwater flow directions determined from all borings.

french drains. Also included in the report was documentation on site activity noted on each year of available photography, the two geologic analyses, and pertinent information obtained from agency records and Eastman Kodak, including site contents. The company responded to the committee's concerns by proposing a drilling and sampling program to determine whether or not problems existed. Laboratory analyses of the initial samples did not indicate that significant quantities of leachate were leaving the site, but an ongoing monitoring program has been recommended by Kodak's consulting geologists to insure that undetected problems do not occur in the future.

The successful investigation of the Weiland Road Landfill and the subsequent agreement by Eastman Kodak to conduct a drilling and sampling program was a result of the information the LRC had been able to gather on site boundaries, drainage, and geology using aerial photographs and general geologic information. The committee was able to work effectively with Kodak because of the accurate and detailed information gathered from historic photos and engineering boring logs.

The sections that follow provide details of the geologic analyses and how these assisted both the company and the committee in identifying areas where testing should be conducted.

GENERAL SITE GEOLOGY

As part of the Monroe County study of this site, a preliminary report on the site geology was prepared by the LCR's geologist. This report was based on published information from general geologic reports and an interpretation of the site geomorphology on old topographic maps and 1930 aerial photography. This report was updated when newer information became available during the investigation.

The Rochester area contains a number of old glacial beach deposits and glacial moraines which exert a significant influence on the local occurrence and movement of groundwater (Figures J-2, J-3). The Weiland Road site is located along an old glacial lake shoreline known as Lake Dawson, which marks an ice-dammed proglacial lake about 200 feet higher than Lake Ontario. Such shorelines are common in western New York and form pronounced ridges of sand and gravel with trends roughly parallel to the present lake shore. As is typical of modern lake shorelines, the glacial beach zones often consist of foreshore beach deposits, backshore storm beach ridges, embayments or lagoons behind the foreshore, and occasional dune fields extending downwind. Because the glacial lake levels

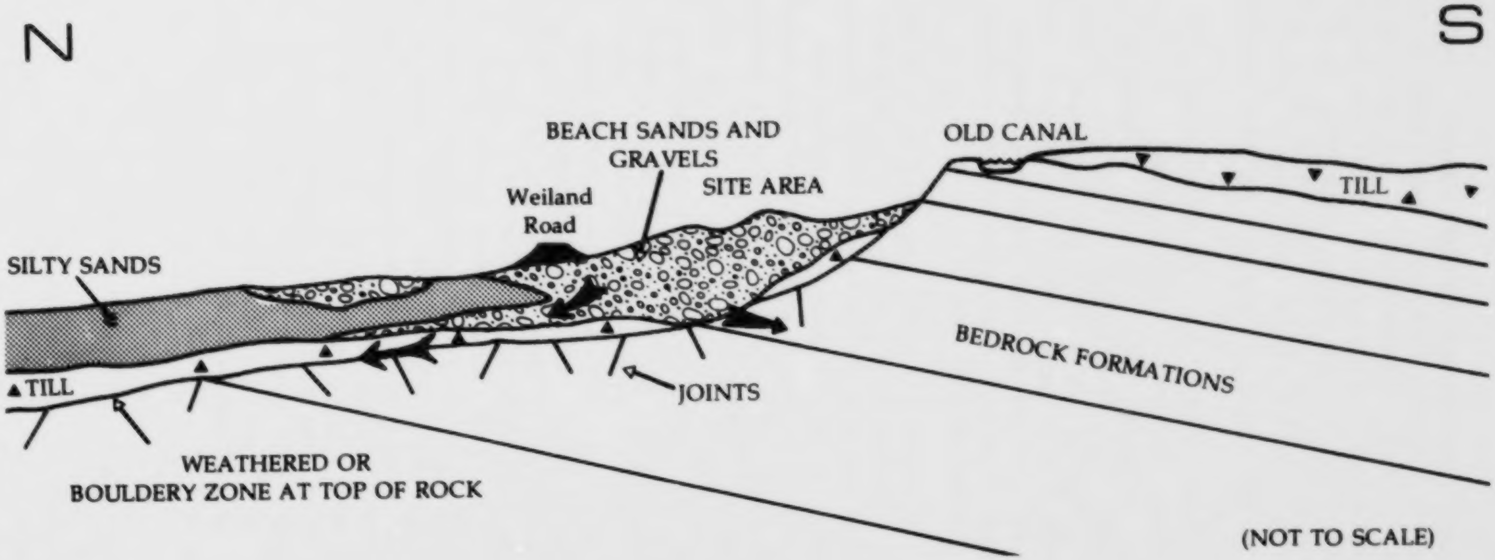

N
S
SILTY SANDS
Weiland Road
BEACH SANDS AND GRAVELS
SITE AREA
OLD CANAL
TILL
TILL
BEDROCK FORMATIONS
JOINTS
WEATHERED OR BOULDERY ZONE AT TOP OF ROCK
(NOT TO SCALE)

Figure J-3. Preliminary diagrammatic geologic cross-section completed prior to boring data obtained during later portion of study: Weiland Road industrial landfill.

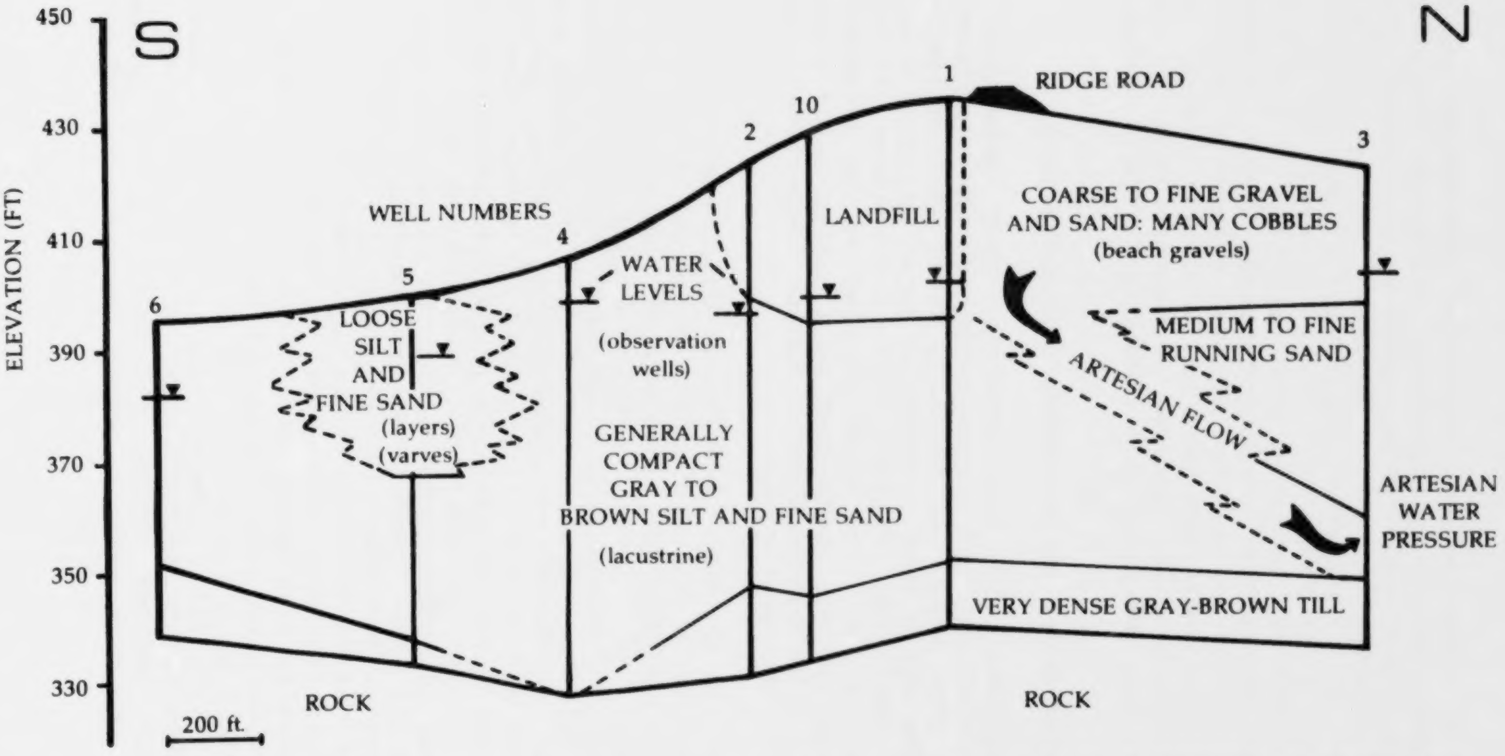
commonly fluctuated as the ice shifted position, many of these features were covered, abandoned, or reworked by wave action as the lake rose and fell repeatedly. In some places permeable sand and gravel deposits are present in broad bands up to a mile wide. In other locations the beaches and sandbars are relatively narrow but may be up to several tens of feet thick. These old beach deposits have commonly been used for gravel extraction followed by waste disposal in the abandoned pits.

The Weiland Road site is located along an obvious beach ridge with parallel stream tributaries (Paddy Hill Creek) developed in the "ridge and swale" topography immediately upslope from the main beach (Figure J-2). Immediately behind this beach shore complex is a 50-foot subdued escarpment formed by the local sandstones and the dolomitic Rochester shale (Figure J-3). Wave action at the highest Dawson stage may have eroded this zone and created the pronounced change in slope that is present on the topographic maps.

Because this landfill was obviously sited in an area of potential sand and gravel deposits, an effort was made to determine the nature of the local soils and overburden. Borings from available sewer and highway construction projects were sought, and records of sand and gravel operations along other shoreline segments were reviewed. A set of borings through a former waste disposal site on another beach ridge east of the Genesee River was located (Figure J-4). These data allowed the project geologist to infer subsurface geology at the Weiland Road site. Shallow sewer borings a mile west of the site indicated that rock was relatively shallow. However, descriptions of gravel extraction operations elsewhere in Rochester suggested that the shoreline deposits were often extremely variable in thickness over short distances. Water levels in existing borings in the general area were from 1 to 5 feet below the surface and overburden consisted of 12 to 20 feet of silt, fine sand, gravel, and boulders. Borings on the site proper, supplied by Kodak, indicated that glacial till underlay portions of the site along its northern edge. Borings near Latona Road on the west end of the site indicated very loose sediment and organic material close to the bedrock surface and only about twenty feet below the original ground surface. These data were included in the initial report by the committee's geologist. This geologic analysis indicated the potential groundwater flow direction to be to the northwest, and further subsurface testing was recommended.

REMEDIAL ACTION AND SITE INVESTIGATION

From a geologic standpoint, the regional geologic information available for the general area, especially for the old glacial shorelines, enabled the geologist to develop a



450
430
410
390
370
350
330
ELEVATION (FT)
S
N
200 ft.
WELL NUMBERS
6
5
4
2
10
1
3
RIDGE ROAD
LOOSE SILT AND FINE SAND (layers) (varves)
WATER LEVELS (observation wells)
GENERALLY COMPACT GRAY TO BROWN SILT AND FINE SAND (lacustrine)
LANDFILL
COARSE TO FINE GRAVEL AND SAND: MANY COBBLES (beach gravels)
MEDIUM TO FINE RUNNING SAND
ARTESIAN FLOW
ARTESIAN WATER PRESSURE
VERY DENSE GRAY-BROWN TILL
ROCK
ROCK

Figure J-4. Interpretative geologic cross-section: Culver-Ridge Shopping Center Site.

reasonable hydrogeologic model of groundwater conditions prior to expensive site investigations. Although this model included generalizations made from sites up to several miles away, the trend of potentially sandy deposits was predictable and the movement of groundwater (westward or northwestward) along the former course of Paddy Hill Creek appeared likely. The model was sufficiently complete that selection of additional drilling sites was relatively straightforward. All concerned parties were satisfied that the minimal number of initial monitoring wells located along the west and northwest edges of the site were sufficient to address concerns relating to groundwater contamination and potential leachate movement offsite (Figure J-2).

Groundwater Movement and Water Well Locations

Subsequent to the concerns over potential groundwater contamination and the proper design of the leachate collection system, the issue of drinking water well contamination over a wider area was raised. Drinking water wells were known to have existed near the Weiland Road site between the mid 1930's and the early 1970's. One house located on the northwest corner of the property was connected to a public water supply system in 1979 after the Monroe County Health Department detected acid magenta in the well water.

While a general search was being made to locate or verify the existence of any individual water wells within 1000 feet of the site, additional information concerning the movement of groundwater in the bedrock became available. Ongoing engineering studies and deep sewer tunnel construction in the City of Rochester produced additional information concerning the localized movement of groundwater. Water pressure tests in borings in all of the local bedrock units demonstrated that significant water movement is probably confined to the upper few tens of feet of jointed rock. Fault zones with small vertical displacements were encountered in tunnel drilling operations. Small faults were found to exert significant controls over the amount and direction of groundwater movement in bedrock. A number of potential fault zones have been located in the western portion of the city, some close to the Weiland Road site, and a more realistic approximation of zones of enhanced groundwater flow could have been prepared if any individual, private, or public water supplies were found to be in use in the vicinity of the landfill site. Aside from these fault zones with their potentially higher permeability, it does not appear that any of the local bedrock units is generally very permeable, except close to the rock surface where weathering and jointing are present.

Usefulness of Geologic and Engineering Data

Preliminary and improved hydrogeologic models of the Weiland Road site and its surroundings enabled the site to be evaluated without expensive testing by outside agencies. The localization of two potential areas of concern involving groundwater movement beneath the site was possible with existing engineering records and subsurface geologic information. The information from other projects on and adjacent to the site minimized the need for additional wells.

GLOSSARY

ablation till: Loosely consolidated rock debris that accumulated in place as the glacial ice melted. (see also glacial till)

acid magenta: A dye that is produced by oxidation of a mixture of aniline and toluidines and yields a brilliant bluish red.

aeration booms: Mechanical aeration or mixing booms visible above settling tanks at sewage treatment facilities. Allows discrimination of sewage treatment facility from similar-sized circular storage tanks on aerial photographs.

alluvial deposits: A general term for unconsolidated detrital material deposited by a stream in its channel or on a floodplain.

aquifer: A body of rock or soil sufficiently permeable to conduct groundwater and to yield significant quantities of water to wells or springs.

attenuation: The reduction of ionic concentrations in solutions by natural earth materials by the processes of cation exchange with clays or similar mechanisms.

backshore storm beach ridges: The shore zone between mean high water and the upper limit of shore-zone processes that is acted upon only by severe waves or during unusually high tides.

bathtub effect: An overflow effect commonly seen in landfills located in impermeable clay soils where infiltration of precipitation through waste and cover materials exceeds the capacity of the soil to absorb the normal rainfall. Springs of leachate may appear around the site perimeter.

berm: A narrow bench or dike-like barrier of earth commonly built to contain spills or liquid waste.

boring logs: Engineering and geologic descriptions of exploration drill holes commonly utilized during the design and planning phases of construction projects.

borrow pit: An excavated area where earth materials (not rock) have been removed to use for fill or construction elsewhere.

caliche: Calcareous material of secondary accumulation near the surface of soils in arid to semi-arid regions. Such deposits indicate the upward movement of groundwater (evaporation) and decrease soil permeability.

cation exchange capacity: The capacity of a material (commonly clay minerals) to exchange weakly bound ions with preferred ions that occur in groundwater or leachate.

cell excavation construction: The more recent methods of landfill construction whereby adjacent trenches are excavated in turn and daily waste is compacted and covered by soil in 6" to 12" lifts.

channel: A linear depression such as is commonly associated with an existing stream bed or an abandoned river system or irrigation trench.

clean fill: Inert materials, especially soils or rock that are commonly used to fill depressions prior to construction of large buildings, parking lots or housing developments.

continental glaciation: The resulting effects of the processes of ice deposition and erosion by large ice sheets which covered the northern United States until 13,000 to 20,000 years ago.

dipping rock layers: Sedimentary rocks usually occur in layered sequences which are originally horizontal on the ocean floor, but may become tilted and eroded after large scale earth movements have occurred.

drag lines: Large scoops or buckets on the end of chains or cables attached to crane-like booms are sometimes used to excavate sand or gravel. Such methods often leave visible, fan-like marks visible on aerial photographs.

drainage basins: A relative term referring to a master stream and its tributaries and the surface over which they collect runoff. The term may be used to denote a feature as large as the Mississippi River System or as small as a gully system in a small field.

drainage divide: The highest point of land separating one drainage basin from all adjacent drainage basins and forming a continuous boundary that includes all the area draining into the master stream.

drumlins: Elongate hills resulting from glacial deposition and erosion under ice sheets. Their long axes are parallel to the ice flow direction and their bluntest slopes point in the direction from which the ice advanced.

effluent: A liquid discharge, such as waste from a factory or water from a sewage treatment facility.

enhanced groundwater flow: Groundwater flow that is being increased in a particular direction due to variations in the factors (i.e., permeability) that control flow.

environmental atlas: An atlas containing maps and descriptions of parameters useful in environmental planning, such as soil types, rainfall, land use, etc.

extraction activities: The activities associated with sand and gravel pits, borrow pits, or rock quarry operations.

faults: Fractures in earth materials, usually bedrock, that develop when sudden earth movements occur. Such fractures may be planar features or zones of crushed and broken rock and often permit groundwater to migrate more rapidly than through unfractured materials.

fill: See clean fill. (Some processed material such as cinders or furnace slag may be used as fill material).

filling activity: The activity (spreading, hauling, etc.) that is associated with the emplacement of fill.

fly ash: Particulate matter usually associated with a gas stream, especially in the stack gases of a coal-fired electric generating plant. May be referred to as cinders or ash.

foreshore beach deposits: Deposits formed on the outer, seaward-(lakeward) sloping zone of a beach, commonly between high and low water marks.

geologic quadrangle maps: Maps showing the distribution of geologic formations (commonly shown without surficial soils) at the earth's surface. These maps are usually compiled at scales of 1:24,000 or 1:63,360 on topographic base maps.

geomorphologic: Pertaining to the shape of the land surface as influenced or shaped by geologic processes (glaciers, rivers, etc.).

glacial lodgement tills: A glacial till formed of the rock debris transported beneath a glacier and therefore more compact and generally less permeable than ablation till.

glacial meltwater: The water discharged by a melting glacier, which forms channels or deposits similar to those formed by normal streams.

glacial moraine: Generally loosely consolidated deposits of glacial till, sand, or gravel deposited near the edge of a stationary ice front and rising conspicuously above the surrounding terrain. Often linear or ridge-shaped.

glacial till (or till): Unsorted rock debris (clay, silt, sand, gravel) deposited by a glacier. Such deposits may be highly variable in texture or composition and are often erroneously assumed to be relatively impermeable.

groundwater flow path: The pathway followed by groundwater as it moves through bedrock or soil formations.

hard pan: Unusually hard or naturally cemented soil layers (such as caliche). The term may be informally used by some laymen to refer to glacial till soils that are very compact at depth.

hydraulic conductivity (permeability coefficient): The rate of flow of water (volume per unit area) under a unit hydraulic gradient (45 slope) at a specified temperature.

hydraulic gradient: In an aquifer, the rate of change of total head (pressure) per unit of distance of flow at a given point in a given direction.

hydrogeologist: A geologist whose special interest, training, or experience is the study of ground and surface water, its occurrence, movement, and associated engineering problems.

ice-dammed proglacial lake: A glacial lake that owes its origin to the damming action of a glacier where the adjacent land forms an enclosing basin. The lake cannot be maintained when the glacial barrier melts or retreats. Commonly found in front of a glacier.

immiscibility: Two phases, commonly liquids that cannot completely dissolve in one another (such as oil and water).

indurated: Rock or soil that has been hardened or consolidated by pressure or cementation.

inlet plume: A visible discolored plume of a liquid that is clearly visible as it enters a body of water of a different color or having a different sediment content.

ionic species: Chemically dissociated substances (elements) in a fluid medium, such as sodium and chloride ions formed when salt dissolves in water.

joints: Natural breaks in bedrock along which no apparent movement has occurred (unlike faults). Caused by large scale earth movements or gradual unloading of the earth's crust.

karst: Terraine in which the dominant surface relief is due to groundwater solution of soluble carbonate rock (limestone or dolomite).

lake clays: Fine-grained sediment resulting from settling of suspended particles in quiet lake waters. Commonly these deposits are conspicuously layered and impermeable.

laterite soil: An iron-rich, reddish soil that is sometimes hard enough to cut into building stone; may form hardpans.

leachate: A solution formed by the percolation of water through materials containing other fluids or finely divided or soluble constituents. Commonly used in reference to landfills.

lifts: Refers to the method of landfill operation where the daily waste is compacted and covered by soil in layers, commonly 1 ft. to 4 ft. thick with 6" to 12" soil layers.

lodgement till: See glacial lodgement till.

mass wasting: A general term for the downslope transport of soil and rock material under the influence of gravity and aided by water content.

matrix: The finer particles of a soil or overburden within which the larger fragments appear to be contained.

metric conversions: 1 mile = 1.609 kilometers
1 foot = 30.480 centimeters
1 inch = 2.540 centimeters
1 acre = .405 hectares or 4047 square meters

moraine: See glacial moraine.

mylar: See translucent drafting film.

orthophotomaps: Planimetric maps on a photographic base. Commonly produced at a large scale for land use planning or similar activities.

outcrops: Places on the earth's surface where bedrock formations are naturally exposed or visible, as in a cliff face or road cut.

outwash: The sorted deposits (usually sand or gravel) that are laid down by glacial meltwater (see glacial meltwater).

overburden: A general term referring to all the unconsolidated rock debris overlying the bedrock. Engineers sometimes use the terms overburden and soil interchangeably. Geologists commonly infer that "soil" is the upper few feet of overburden that has been obviously weathered and is often divisible into secondary zones of variable color or texture.

perched: Refers to a water table that is separated from the general, regional groundwater table. The perched water table is located on top of a localized impermeable layer.

permeable: Capable of transmitting fluids, especially water, at a significant rate, generally in inches or feet per hour for highly permeable materials.

planimetric maps: A map which has features located accurately in the horizontal sense. Also a map without topographic contours. However, topographic maps may be planimetrically correct.

plat book maps: Historic maps dating back to the early 1900's often found in municipal offices or public libraries. These maps delineate property boundaries and identify owners and acreage.

Pleistocene: The geologic epoch during which the earth was partially covered by large ice sheets. The latest interval (Wisconsin Stage) lasted from about 75,000 to 13,000 years ago in the northern U.S.

preferred orientations: The nonrandom orientation of planar or linear fabric in rocks or overburden. Pebbles, sand grains, or joints may be oriented preferentially by the directional processes or forces that deposited or formed them.

profiles: A line representing the shape of a surface in cross-section, such as the profile of a valley from one side to the other.

property line maps: Maps commonly used by municipal agencies (tax assessors, etc.) that show all property boundaries accurately, to scale.

relict glacial lake shorelines: Well sorted sandy to gravelly deposits marking the former positions of the edges of proglacial lakes (see ice-dammed proglacial lake).

ridge and swale topography: Low ridges and linear depressions commonly associated with foreshore and backshore beach zones.

saturated zone: The zone in the overburden in which all the pore spaces are filled with water or leachate (contrasted with the zone of aeration above it).

sedimentary depositional mechanisms: All of the processes which may occur when sediments are formed and laid down by geologic processes (glaciers, rivers, wind).

sedimentological: Pertaining to the properties of sediments or the factors that affect their formation.

seeps: Small springs where natural groundwater issues from the ground. Also used to describe leachate oozing from landfills (see bathtub effect).

soil: The term soil has different meanings and usages among geologists, engineers, and soil scientists (see overburden).

solution zones: Zones in rock, especially limestone, where the action of flowing groundwater has produced enlarged passages for water movement. .Joints or faults are places where this may occur.

spoil: Waste material left from mining, quarrying or other excavating activities that is not usable (for example finely broken rock from a building stone quarry).

standard industrial code (SIC): A standard method of classifying businesses by the type of activity in which they are engaged.

stereographic pairs: Sequential, overlapping photographs taken from slightly different positions and allowing a scene to be viewed in 3-dimensions.

stockpiles: Materials stored in proximity to a manufacturing or construction activity, i.e., road salt, lumber, building stone, concrete aggregate, etc.

stratigraphy: The study of stratified rock (sedimentary rocks) and the processes that form them. Also the arrangement of strata (layers) in a particular region.

street directories: A compilation of information which includes a register of property owners by street and address.

structures: A megascopic feature of a rock mass, such as a fault, joint, or layer.

surface impoundment: A surface depression for the storage of liquid waste.

surficial and bedrock geology: The surficial geology of a region is usually contrasted with or studied separately from the bedrock geology. "Surficial" usually refers to the unconsolidated materials (overburden) such as the glacial sediments, alluvium, or soil.

tailing piles: Rock debris left over from washed or milled ore that is considered as too low grade to be treated further.

tectonic stresses: Stresses or forces within the earth that cause movement (faulting or folding) of rock layers.

topographic maps: A map showing the relief of the land surface by means of contour lines.

translucent drafting film: A plastic base (usually mylar) drafting material having the appearance of frosted glass.

unconsolidated overburden: Overburden that is not compacted or cemented to such an extent that it cannot be readily excavated by hand or with machinery.

unloading stresses: Forces created by the natural erosion of the earth's surface (or melting of glacial ice) that gradually decrease the pressure on subsurface rocks or sediments and sometimes cause joints or horizontal cracks to appear.

varve: A pair of layers of alternately finer and coarser silt or clay believed to comprise an annual cycle of deposition in a body of still water.

waste piles: Temporary storage of any solid waste.

water balance: The interrelations of all the input or output factors relating to a stream, lake, or aquifer (groundwater and surface water).

water pressure tests: Tests performed in boreholes to determine how readily water enters a rock or soil formation, and hence its permeability.

water table (also groundwater table): The surface of the saturated zone in the rock or overburden, below the zone of aeration, where both air and water may occur in the pore spaces of rocks and soils.

water well: A vertical shaft or boring which produces economic quantities of water and is usually located in permeable rock.

weathering: The in situ physical and chemical disintegration of rock and soil near the earth's surface on exposure to water and atmospheric agents.

well fields: Groups of wells drilled into the same aquifer to increase total yield or to allow alternate pumping when yields are inadequate or when excessive pumping causes damage to well installations.

zones of enhanced permeability: See enhanced groundwater flow.

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